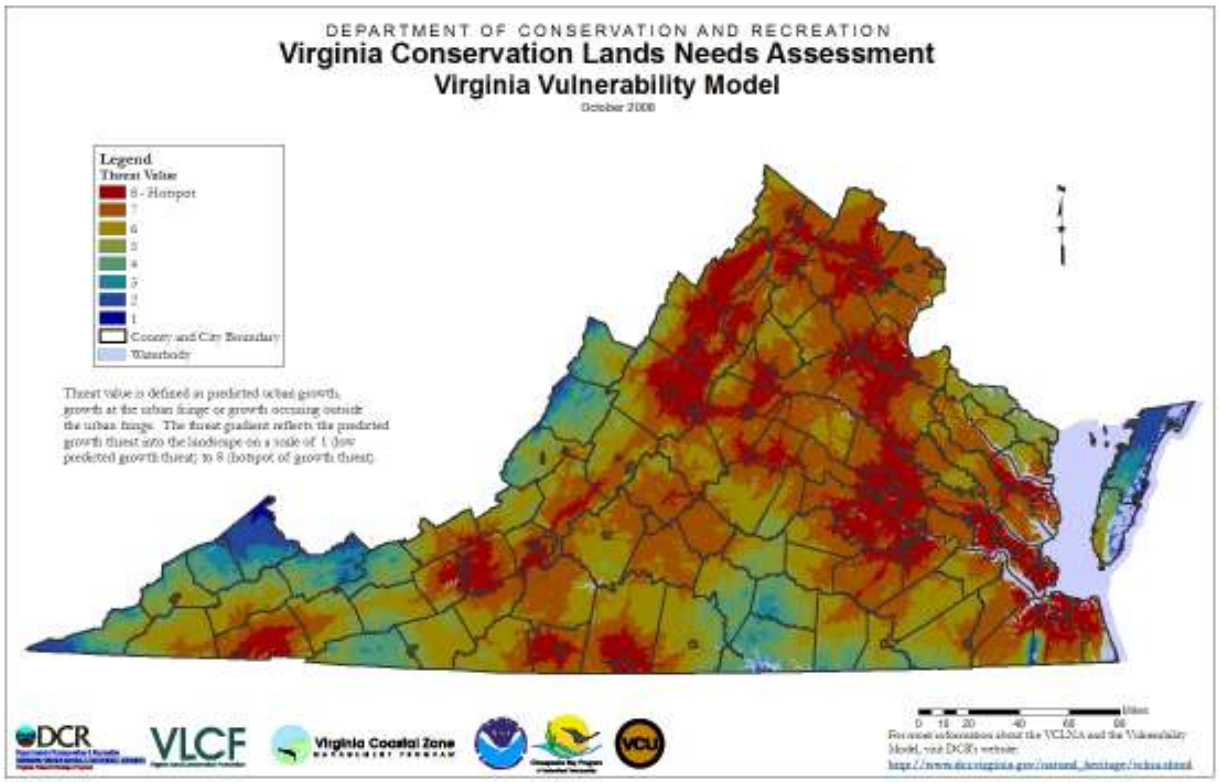
Virginia Conservation Lands Needs Assessment
Virginia Vulnerability Model



Virginia Department of Conservation and Recreation Division of Natural Heritage
Virginia DEQ Coastal Zone Management Program

DCR
Department of Conservation & Recreation
CONSERVING VIRGINIA'S NATURAL & RECREATIONAL RESOURCES
Virginia Natural Heritage Program

Virginia Coastal Zone
MANAGEMENT PROGRAM

This work is funded by the Virginia Coastal Zone Management Program at DEQ through grant #NAO5NOS4191180 from the National Oceanic and Atmospheric Administration to the Virginia Department of Conservation and Recreation's Natural Heritage Program

TABLE OF CONTENTS

INTRODUCTION 1
Application of the Vulnerability Model 2
Deliverables 2
METHODOLOGY 3
Base Data 3
Livable area road density 6
Housing Allocation Procedure 6
Lot Size Estimation 7
Statistical Analyses 7
Growth Hot Spots 8
Threat Grids 10
Model Validation 12
Discussion 12
FUTURE APPLICATIONS 13
Additional Data Incorporation 13
REFERNCES 14
Table 1. List of cities and counties used in the final regression model. 15
Figure 1. PDC 1 LENOWISCO Vulnerability Model 16
Figure 2. PDC 1 LENOWISCO Urban Vulnerability Model. 17
Figure 3. PDC 1 LENOWISCO Urban Fringe Vulnerability Model. 18
Figure 4. PDC 1 LENOWISCO Outside the Urban Fringe Vulnerability Model. 19
Figure 5. PDC 2 Cumberland Plateau Vulnerability Model. 20
Figure 6. PDC 2 Cumberland Plateau Urban Vulnerability Model. 21
Figure 7. PDC 2 Cumberland Plateau Urban Fringe Vulnerability Model. 22
Figure 8. PDC 2 Cumberland Plateau Outside the Urban Fringe Vulnerability Model. 23
Figure 9. PDC 3 Mount Rogers Vulnerability Model 24
Figure 10. PDC 3 Mount Rogers Urban Vulnerability Model 25
Figure 11. PDC 3 Mount Rogers Urban Fringe Vulnerability Model 26
Figure 12. PDC 3 Mount Rogers Growth Outside the Urban Fringe Vulnerability Model . 27
Figure 14. PDC 4 New River Valley Urban Vulnerability Model 29
Figure 15. PDC 4 New River Valley Urban Fringe Vulnerability Model 30
Figure 16. PDC 4 New River Valley Growth Outside the Urban Fringe Vulnerability Model 31
Figure 17. PDC 5 Roanoke Valley-Alleghany Regional Commission Vulnerability Model. 32
Figure 18. PDC 5 Roanoke Valley-Alleghany Regional Commission Urban Vulnerability Model. 33
Figure 19. PDC 5 Roanoke Valley-Alleghany Regional Commission Urban Fringe Vulnerability Model. 34
Figure 20. PDC 5 Roanoke Valley-Alleghany Regional Commission Outside the Urban Fringe Vulnerability Model. 35
Figure 21. PDC 6 Central Shenandoah Vulnerability Model. 36
Figure 22. PDC 6 Central Shenandoah Urban Vulnerability Model. 38
Figure 23. PDC 6 Central Shenandoah Urban Fringe Vulnerability Model. 40
Figure 24. PDC 6 Central Shenandoah Outside the Urban Fringe Vulnerability Model. 42

Figure 25. PDC 7 Northern Shenandoah Valley Regional Commission Vulnerability Model 44
Figure 26. PDC 7 Northern Shenandoah Valley Regional Commission Urban Vulnerability Model. 45
Figure 27. PDC 7 Northern Shenandoah Valley Regional Commission Urban Fringe Vulnerability Model. 46
Figure 28. PDC 7 Northern Shenandoah Valley Regional Commission Outside the Urban Fringe Vulnerability Model. 47
Figure 29. PDC 8 Northern Virginia Regional Commission Vulnerability Model. 48
Figure 30. PDC 8 Northern Virginia Regional Commission Urban Vulnerability Model. ... 49
Figure 31. PDC 8 Northern Virginia Regional Commission Urban Fringe Vulnerability Model. 50
Figure 32. PDC 8 Northern Virginia Regional Commission Outside the Urban Fringe Vulnerability Model. 51
Figure 33. PDC 9 Rappahannock-Rapidan Regional Commission Vulnerability Model. 52
Figure 34. PDC 9 Rappahannock-Rapidan Regional Commission Urban Vulnerability Model. 53
Figure 35. PDC 9 Rappahannock-Rapidan Regional Commission Urban Fringe Vulnerability Model. 54
Figure 36. PDC 9 Rappahannock-Rapidan Regional Commission Outside the Urban Fringe Vulnerability Model. 55
Figure 37. PDC 10 Thomas Jefferson Planning District Commission Vulnerability Model. 56
Figure 38. PDC 10 Thomas Jefferson Planning District Commission Urban Vulnerability Model. 57
Figure 39. PDC 10 Thomas Jefferson Planning District Commission Urban Fringe Vulnerability Model. 58
Figure 40. PDC 10 Thomas Jefferson Planning District Commission Outside the Urban Fringe Vulnerability Model. 59
Figure 41. PDC 11 Region 2000 Local Government Council Vulnerability Model. 60
Figure 42. PDC 11 Region 2000 Local Government Council Urban Vulnerability Model. . 61
Figure 43. PDC 11 Region 2000 Local Government Council Urban Fringe Vulnerability Model. 62
Figure 44. PDC 11 Region 2000 Local Government Council Outside the Urban Fringe Vulnerability Model. 63
Figure 45. PDC 12 West Piedmont Planning District Commission Vulnerability Model. ... 64
Figure 46. PDC 12 West Piedmont Planning District Commission Urban Vulnerability Model. 65
Figure 47. PDC 12 West Piedmont Planning District Commission Urban Fringe Vulnerability Model. 66
Figure 48. PDC 12 West Piedmont Planning District Commission Outside the Urban Fringe Vulnerability Model. 67
Figure 49. PDC 13 Southside Planning District Commission Vulnerability Model. 68
Figure 50. PDC 13 Southside Planning District Commission Urban Vulnerability Model. . 69
Figure 51. PDC 13 Southside Planning District Commission Urban Fringe Vulnerability Model. 70
Figure 52. PDC 13 Southside Planning District Commission Outside the Urban Fringe Vulnerability Model. 71
Figure 53. PDC 14 Commonwealth Regional Council Vulnerability Model. 72

Figure 54. DC 14 Commonwealth Regional Council Urban Vulnerability Model. 73
Figure 55. PDC 14 Commonwealth Regional Council Urban Fringe Vulnerability Model.. 74
Figure 56. PDC 14 Commonwealth Regional Council Growth Outside the Urban Fringe Vulnerability Model. 75
Figure 57. PDC 15 Richmond Regional Vulnerability Model. 76
Figure 58. PDC 15 Richmond Regional Urban Vulnerability Model. 77
Figure 59. PDC 15 Richmond Regional Urban Fringe Vulnerability Model. 78
Figure 60. PDC 15 Richmond Regional Outside the Urban Fringe Vulnerability Model..... 79
Figure 61. PDC 16 George Washington Regional Commission Vulnerability Model. 80
Figure 62. PDC 16 George Washington Regional Commission Urban Vulnerability Model. 81
Figure 63. PDC 16 George Washington Regional Commission Urban Fringe Vulnerability Model. 82
Figure 64. PDC 16 George Washington Regional Commission Outside the Urban Fringe Vulnerability Model. 83
Figure 65. PDC 17 Northern Neck Vulnerability Model. 84
Figure 66. PDC 17 Northern Neck Urban Vulnerability Model 85
Figure 67. PDC 17 Northern Neck Urban Fringe Vulnerability Model. 86
Figure 68. PDC 17 Northern Neck Outside the Urban Fringe Vulnerability Model. 87
Figure 69. PDC 18 Middle Peninsula Vulnerability Model. 88
Figure 70. PDC 18 Middle Peninsula Urban Vulnerability Model 89
Figure 71. PDC 18 Middle Peninsula Urban Fringe Vulnerability Model. 90
Figure 72. PDC 18 Middle Peninsula Outside the Urban Fringe Vulnerability Model. 91
Figure 73. PDC 19 Crater Vulnerability Model. 92
Figure 74. PDC 19 Crater Urban Vulnerability Model. 93
Figure 75. PDC 19 Crater Urban Fringe Vulnerability Model. 94
Figure 76. PDC 19 Crater Outside the Urban Fringe Vulnerability Model. 95
Figure 77. PDC 22 Accomack-Northampton Planning District Commission Vulnerability Model. 96
Figure 78. PDC 22 Accomack-Northampton Planning District Commission Urban Vulnerability Model. 97
Figure 79. PDC 22 Accomack-Northampton Planning District Commission Urban Fringe Vulnerability Model. 98
Figure 80. PDC 22 Accomack-Northampton Planning District Commission Outside the Urban Fringe Vulnerability Model 99
Figure 81. PDC 23 Hampton Roads Planning District Commission Vulnerability Model. 100
Figure 82. PDC 23 Hampton Roads Planning District Commission Urban Vulnerability Model 101
Figure 83. PDC 23 Hampton Roads Planning District Commission Urban Fringe Vulnerability Model 102
Figure 84. PDC 23 Hampton Roads Planning District Commission Outside the Urban Fringe Vulnerability Model 103
Figure 85. Coastal Zone Vulnerability Model. 104
Figure 86. Coastal Zone Urban Vulnerability Model. 105
Figure 87. Coastal Zone Urban Fringe Vulnerability Model. 106
Figure 88. Coastal Zone Outside the Urban Fringe Vulnerability Model. 107
Figure 89. Virginia Vulnerability Model. 108
Figure 90. Virginia Urban Vulnerability Model. 109

Figure 91. Virginia Urban Fringe Vulnerability Model. 110
Figure 92. Virginia Outside the Urban Fringe Vulnerability Model. 111

INTRODUCTION

The Virginia Vulnerability Model was developed in an effort to map predicted growth in Virginia. The growth prediction may be used as an indication of potential land use change from the current use to an urban or suburban use.

In an effort to map the predicted growth in Virginia, four models were developed:

- Virginia Urban Vulnerability Model which shows predicted urban growth
- Virginia Urban Fringe Vulnerability Model which shows the predicted urban fringe, or metropolitan fringe growth.
- Virginia Vulnerability beyond the Urban Fringe Model which show the predicted growth beyond the urban fringe (ex-urban growth).
- Virginia Vulnerability Model which shows a composite of all the vulnerability models integrated into one model representing growth pressures across the urban, suburban and rural landscape.

(E. H. Wilson et al. 2003, R. E. Heimlich and W. D. Anderson, 2001)

The Vulnerability models represent predicted urban growth into the landscape and it is incumbent on the end user to assess what growth represents in terms of sprawl (E. H. Wilson et al. 2003). Urban growth that continues in an unplanned fashion, particularly into previously undeveloped areas, typically has a negative effect on the environment, ecologically, economically and socially (E. H. Wilson et al. 2003, R. E. Heimlich and W. D. Anderson, 2001). As growth and subsequent development continues across the state, remaining resources are being damaged and irretrievably lost.

The development of a GIS vulnerability model puts growth into context in relation to the state; it provides a large scale picture of growth patterns across jurisdictional boundaries. Traditionally state and local government has been reactive to population growth, and while some efforts are being made to control growth, often "strategically directing development to the most favorable areas well in advance of urban pressures" does not happen (R. E. Heimlich and W. D. Anderson, 2001).

The models, detailed above, represent different growth effects. The only model showing all predicted growth effects is the Virginia Vulnerability Model. The Urban Vulnerability Model shows the predicted urban growth into the landscape, it does not include the suburban or rural growth pressures. The Urban Fringe Vulnerability Model shows the predicted urban fringe, also typically called suburban, growth into the landscape, it does not include urban or rural growth pressures. The Beyond the Urban Fringe Vulnerability Model shows predicted growth outside of the urban fringe, or rural growth pressures, it does not include urban or suburban growth pressures.

The Vulnerability model may serve as a guide to state and local government, consultants, and developers as to the location of growth patterns, particularly in relation to the current environment. The model can be used alone or integrated with other datasets, such as the VCLNA Cultural Model or Ecological Model, to identify which cultural resources or ecological cores are most at risk to these growth pressures. The model may also be used to help guide local land use planners in the development of their comprehensive plans in an effort to control growth and subsequent development within their jurisdiction. It is important to look at the landscape as a whole and assess how growth may impact the environment, what remaining farmland or timberland is available or how water quality will be affected, before more development is introduced.

The models serve as part of a larger green infrastructure plan, which aims to model where Virginia's conservation priorities are located to facilitate an integrated approach to planning and development. For information on the Virginia Conservation Lands Needs Assessment and the Green Infrastructure Modeling effort, please visit the VCLNA website at http://www.dcr.virginia.gov/dnh/vclna.htm.

Application of the Vulnerability Model

Some general categories of uses to which the vulnerability model can be applied include:

- Targeting – to identify targets for protection activities
- Prioritizing – to provide primary or additional justification for key conservation land purchases and other protection activities.
- Local planning – guidance for comprehensive planning and local ordinance and zoning development.
- Assessment – to review the state of the land and assess growth in context of the landscape
- Land Management – to guide property owners and public and private land managers in making land management decisions that enhance ecological, social and economic services
- Public Education – to inform the citizenry about the development and growth of their community, helping them stay informed about the state of growth of their area.

The Vulnerability Model serves as a base model, upon which local datasets can be added, such as zoning information, comprehensive plans, parcel data, septic suitability information and any other datasets which may help drive local decision making processes. The constraints of a statewide model include the incorporation of existing, statewide GIS datasets. Incorporation of datasets such as individual locality septic sewer information may not be available statewide and are not included in the model since the effect would skew overall model results. Individuals should use the Vulnerability Models and incorporate any additional datasets as needed to make informed decisions. It is at this local level the end user may be able to draw his / her own conclusions on growth, sprawl and the impending consequences.

Deliverables

Maps will be produced for the entire Coastal Zone and the Planning District Commissions and included as part of the final report. The report will be available online and on CD by request and include:

- Maps showing:
    - Virginia Urban Vulnerability Model
    - Virginia Urban Fringe Vulnerability Model
    - Virginia Vulnerability outside the Urban Fringe Model
    - Virginia Vulnerability Model which shows a composite of all the vulnerability models integrated into one model representing growth pressures across the urban, suburban and rural landscape.
- A report detailing the methodology
- Metadata
- Four (4) GRID coverages representing the above detailed models.
- Four (4) shapefiles representing the above detailed models.
- An ArcGIS geodatabase with threat feature classes.

METHODOLOGY

Data methods were based on the Chesapeake Bay Program's Vulnerability Model. The methodology has been modified in some places and changed in others to reflect Virginia specific needs. Please refer to the Chesapeake Bay Program's Resource Lands Assessment for a review of the CPB RLA Vulnerability Model methodology (http://www.chesapeakebay.net/rla.htm).

Base Data

LAYER	DESCRIPTION	SOURCE
rd3_33x33_0	Road density grid	• Tiger Roads (2000)
slope_pct22	Grid representing slope greater than or less than and equal to 22 %	• National Elevation Dataset
blkgrp_90	1990 Census block group boundaries with associated summary file information	• Geography Network (polygon shapefile) • American Fact Finder (SF tables)
blkgrp_00	2000 Census block group boundaries with associated summary file information	• Geography Network (polygon shapefile) • American Fact Finder (SF tables)
zero_blks	2000 Census block group grid that has 0 population and 0 housing units	• blkgrp_00
wwte	Grid representing livable area	• RESAC 2000
exlands_2	Road density in livable area	• rd3_33x33_0 • slope_pct22 • zero_00blks • wwte
rddent_90	Census block group road density	• blkgrp_90 • rd3_33x33_0
rddent_00	Census block group road density	• blkgrp_00 • rd3_33x33_0
rdalloc_90	Relative percentage of road density per census block group pixel	• exlands_2 • rddent_90
rdalloc_00	Relative percentage of road density per census block group pixel	• exlands_2 • rddent_00
shu_90	Housing unit block group grid	• blkgrp_90
shu_00	Housing unit block group grid	• blkgrp_00
shu_90pix	Single family detached housing units per pixel grid	• shu_90
shu_00pix	Single family detached housing units per pixel grid	• shu_00
regnet	1 square mile grid	• Generated in ArcINFO
vaimp90	1990 Impervious surface image of the Chesapeake Bay portion of VA	• Chesapeake Bay Program- RESAC
vaimp00	2000 Impervious surface image of the Chesapeake Bay portion of VA	• Chesapeake Bay Program- RESAC
diffimp90_00	Change in impervious surface from 1990 to 2000	• vaimp90 • vaimp00
f_diffimp	Filtered change in impervious surface.	• diffimp90_00

imp90_00_2	Grid where pixel value is considered to be at least 20%.	• f_diffimp
hspots_imp	Impervious hotspot	• regnet
urban core	Urban areas	• regnet • RUCA table • 2000 census block group
urban commute	Suburban areas / urban fringe area	• regnet • RUCA table • 2000 census block group
rural	Area outside the urban fringe	• regnet • RUCA table • 2000 census block group
hspots_core	Urban hotspots	• regnet
hspots_urbcomm	Urban fringe hotspots	• regnet
hspots_rural	Hotspots outside the urban fringe	• regnet
hspots_1	Combined impervious and urban hotspots	• hspots_imp • hspots_core
hspots_2	Combined impervious and urban fringe hotspots	• hspots_imp • hspots_commute
hspots_3	Combined impervious and rural hotspots	• hspots_imp • hspots_rural
rds_ttime2	Travel time grid	• Tiger Roads (2000)
➢ **threat_1** ➢ **thrt_urb**	Urban growth prediction grid	• hspots_1 • rds_ttime2
➢ **threat_2** ➢ **thrt_urbfrg**	Urban fringe growth prediction grid	• hspots_2 • rds_ttime2
➢ **threat_3** ➢ **thrt_ourbfrg**	Prediction grid for growth outside the urban fringe.	• hspots_3 • rds_ttime2
threat1_x33	Proportional urban growth prediction grid	• threat_1
threat2_x33	Proportional urban fringe growth prediction grid.	• threat_2
threat3_x33	Proportional growth prediction grid for growth outside the urban fringe.	• threat_3
threat1_x33_0	Proportional urban growth prediction grid with NODATA values set to 0.	• threat1_x33
threat2_x33_0	Proportional urban fringe growth prediction grid with NODATA values set to 0.	• threat2_x33
threat3_x33_0	Proportional growth prediction grid for growth outside the urban fringe with NODATA values set to 0.	• threat3_x33
threat_sum	Integrated growth prediction grid.	• threat1_x33_0 • threat2_x33_0 • threat3_x33_0

Projection

Lambert Conformal Conic

NAD 83

Meters

Virginia Grid

- Set snap environment to RESAC
- Generated a 1 square mile grid for the state using the GENERATE and FISHNET commands in ArcINFO.
- Exported to a feature class called REGNET

Slope

In GRID:

- Generated slope from the NED dataset
- Selected slope > 22% = 0, other 1

```
Grid: |> setwindow resac resac <|
Grid: |> setcell resac <|
Grid: |> slope_pct22 = con(slope > 22, 0, 1) <|
```

Roads

- Downloaded TIGER roads
- Calculated a road density grid in a 1km area

```
Grid: |> rd_33x33 = focalsum ((roads), rectangle, 33, 33, data) <|
Running... Value range for c:\projects\rla\vulnerability\data\tiger_rds\rd_33x33 exceeds 100000
and number of unique values exceeds 500.
Please use BUILDVAT if a VAT is required.
Grid: |> buildvat <|
Usage:  BUILDVAT <grid>
Grid: |> buildvat rd_33x33 <|
Grid: |> q <|
```

Census Data

- Downloaded census block group data from ESRI Geography Network (http://arcdata.esri.com/data/tiger2000/tiger_statelayer.cfm).
- Downloaded 2000 Census tabular data from American Fact Finder.
- Downloaded 1990 Census block group tabular data from the SF3A Census Bureau CD.

1990 Block Group	***ATTRIBUTE***
Total Population	P0010001
Total Housing Units (100% count)	H0020001
1-unit, detached housing units (100%)	H0200001

2000 Block Group	***ATTRIBUTE***
Total Population	P001001
Total Housing Units (100%)	H003001
1-unit, detached housing units (100%)	H030002

zero_00blks

- In ArcMap, calculated Block Group 00 poly where total population = 0 and where housing units = 0. Coded the zero_blk as = 0. Reversed selection and calculated zero_blk = 1. Converted to a 30 meter grid.

Livable area road density

- Generate a grid (wwte) where livable areas are classed with a value = 1 and non-livable are classed = 0. Non-livable areas are set as open water, emergent wetlands, transportation and extractive. Used the VA LULC 2003 generated from RESAC and edited in house by Joe Weber.
- Generate a grid (ex_lands2) showing livable area road density values.

  Grid: |> ex_lands2 = rd3_33x33_0 * slope_pct22 * zero_00blks2 * wwte <|

Housing Allocation Procedure

Estimating the total number of single family housing units per pixel

1. Summarize livable area road density grid by unique block group for 1990 and 2000 census block groups.
2. Add a field to blkgrp_90 called rddent_90 and to blkgrp_00 called rddent_00. Calculate the SUM from the summarize into the rddent_tot field.
3. Convert blkgrp_90 to a grid.

   rddent_90 grid
   Field: rddent_tot
   Output cell size: 30 meter
   Output raster: rddent_90

   rddent_00 grid
   Field: rddent_tot
   Output cell size: 30 meter
   Output raster: rddent_00
4. Calculate relative percentage of blk grp road density per pixel.

   Arc: |> grid <|
   Grid: |> setwindow ex_lands2 ex_lands2 <|
   Grid: |> setcell ex_lands2 <|
   Grid: |> rdalloc_90 = (ex_lands2 * 1000000) / rddent_90 <|
   Running... Grid: |> setwindow ex_lands2 ex_lands2 <|
   Grid: |> setcell ex_lands2 <|
   Grid: |> rdalloc_00 = (ex_lands2 * 1000000) / rddent_00 <|
   Running... Grid: |> q <|
5. Convert blkgrps to grids. Set ex_lands2 as snap environment in ArcMap.

   Field: H0200001
   Output cell size: 30 meter
   Output raster: shu_90
   and
   Field: H030002
   Output cell size: 30 meter
   Output raster: shu_00
6. Create single family detached housing units per pixel grid (grid representing proportional # of housing units per pixel).

   Arc: |> grid <|
   Grid: |> setwindow ex_lands2 ex_lands2 <|
   Grid: |> setcell ex_lands2 <|
   Grid: |> shu_90pix = (rdalloc_90 / 1000000) * shu_90 <|
   Running...
   Grid: |> setwindow ex_lands2 ex_lands2 <|

Grid: |> setcell ex_lands2 <|
Grid: |> shu_00pix = (rdalloc_00 / 1000000) * shu_00 <|
Running...

Lot Size Estimation

Development of a regression model to predict lot size from road density values in order to determine land consumption rates.

1. Gather parcel data from select counties (including rural, suburban and urban counties) including zoning information.
2. Parcels not zoned residential as determined by the Municode or Zoning Ordinance deleted. Parcels zoned residential:
    - Attributed with a GIS_Acreage field (double)
    - Acreage calculated
    - Reprojected to Lambert NAD 83
    - Converted to centroid
    - Merged into one feature class
    - In ArcMap, run a spatial join to with REGNET and parcel centroids. Unique ID is REGNET_ID.
3. Set 0 values in the ex_lands2 grid to NO DATA for averaging purposes. Called exld_null.

    Grid: |> exld_null = setnull (ex_lands2 == 0, ex_lands2) <|
4. Use Zonal Statistics to Summarize exld_null in ArcMap (this is the average road density per unique REGNET grid cell).
    - Set snap environment to RESAC
    - Zone dataset: REGNET3
    - Zone field: REGNET_ID
    - Value: exld_null
    - Ignore NoData in calculations
    - Join table
    - Calculate MEAN road density into RDD_exnull attribute in REGNET.
5. Select REGNET where rdd_exldnull > 0 and export as REGNET2.
6. Select from REGNET2 cells that are completely within the Virginia state boundary. This is to remove any fragment areas. Called grid REGENT3.
7. In Access, create queries to calculate the average GIS acreage for each unique REGNET_ID.

Statistical Analyses

Statistical analyses were performed in SAS System 9.1. The full dataset included a total of 35 cities and counties from whom parcel information was obtained (see Table 1). Data for GIS Acreage less than 11 acres was subset for the regression analysis. The acreage was subset at 11 acres to establish a group of data with which to test full and submodels. Acreage above 11 acres was highly variable in the datasets indicating a potential lack of relationship between road density and parcel size.

Univariate statistics were run to test for data normality. Tests on the full dataset indicated non-normal data. The GIS Acreage was transformed with a natural log transformation. Univariate statistics and residual plots indicated data were normal. Transformed data residuals indicated the transformation captured the structure of the data.

8. In SAS System 9.x ran Univariate statistics and plotted residuals to test for normalcy. Transformed the average road density data with a natural log transformation. Tested again for normalcy. Ran regression analyses (PROC REG) to derive regression equation:

LNMeanLotSize = 1.8497 – (0.0128 * [rdd_exld]) + (0.00001154 * ([rdd_exld] * [rdd_exld]))

r-sq = .5365

p < .0001

This regression is applicable for lot sizes up to mean 10 acres as the regression data went up to 10 acre lot sizes total.

Growth Hot Spots

Identifying areas considered to be hot spots for population growth.

1. Add attributes to REGNET3 (double):
    - SHU_90
    - SHU_00
    - SHU90_00
    - CNVRT90_00
    - IMP90_00
2. Summarize shu_90pix and shu_00 pix by REGNET_ID:
    - Set snap environment to RESAC
    - Zone dataset REGNET3
    - Zone field REGNET_ID
    - Value raster shu_90pix and shu_00pix
    - Ignore NoData in calculations
    - Join table
    - Calculate SUM into shu_00 and shu_90 attributes in REGNET.
3. Calculate the change in housing units shu_00 – shu_90 = shu90_00
4. Add a field called MeanLotSize (double). Calculate the natural log and subsequent average lot size using the regression formula:

LNMeanLotSize = 1.8497 – (0.0128 * [rdd_exld]) + (0.00001154 * ([rdd_exld] * [rdd_exld]))

r-square = 0.5365

p-value < .0001

5. Calculate the change in land consumption rate:

CNVRT90_00 = shu90_00 * MeanLotSize

6. In ArcMap, Spatial Analyst, calculated the change in impervious surfaces from 1990 to 2000:
    - Set snap environment to RESAC
    - Raster calculator:
        - diffimp00_90 = [vaimp00_lam83 – vaimp90_lam83]
    - Ran a filter on the difference in impervious surface grid to smooth the data. Ran a 3 x 3 filter because larger filters were altering the data too much. I checked a 9 x 9 filtered grid against the 2000 RESAC data and saw many areas classed as having a large change in impervious in the diffimp grid, when RESAC was not classed as impervious. I felt the 9 x 9 filter misrepresented impervious surface change.

```
Grid: |> setwindow resac <|
Grid: |> setwindow resac resac <|
Grid: |> f_diffimp = focalmean (diffimp00_90, rectangle, 3, 3, data) <|
```

    - Select pixels where change in value is considered to be at least 20%:

```
Grid: |> setwindow resac resac <|
Grid: |> setcell resac <|
Grid: |> imp20_100_2 = select(F_DIFFIMP, 'value > 19') <|
```

7. Summarize change in impervious by REGNET_ID:
    - Set snap environment to RESAC
    - Zone dataset REGNET3

- Zone field REGNET_ID
- Value raster imp20_100_2
- Ignore NoData in calculations
- Join table
- Calculate MEAN into imp90_00_2 attribute in REGNET.

Impervious Hot Spots

Identifying areas considered to represent significant impervious growth.

8. Add a field to REGNET attribute table called LNIMP90_00_2 (double). Take the Log of imp90_00_2 (to normalize the data) and calculate into LNIMP90_00_2.
9. Ran PROC MEANS on LNIMP90_00_2 where values > 0 (alpha = .10, Standard Error = 1.64) (because this is an upper one tail test, so p value = .05). Use the Upper CL to select out impervious hotspots. Upper CL = 3.335.
10. Exported REGNET cells considered to be impervious hot spots:
    - Select by Attribute
    - Where
    - LNimp90_00_2 >= 3.335
    - Export as hspotsimp

Residential Land Conversion Hot Spots

Identifying areas considered to represent significant changes in residential land conversion / land consumption.

11. Downloaded RUCA codes from http://www.ers.usda.gov/briefing/rural/data/ruca/rucc.htm
12. Reclassify tracts per RLA:

Grow Zone	Reclassified category	Original RUCA
"1"	Urban Core Zone =	Metropolitan-area cores (1.0, 1.1)
"2"	Urban Commuting Zone =	Metropolitan-area high commuting (2.x), Metropolitan-area low commuting (3.x), and all secondary flows to Urban Areas (ranging from 5 – 50%).
"3" or "4"	Rural Zone =	All other areas (encompassing Large town, Small town, and Rural areas lacking secondary flow to Urban Areas).

13. Select all RUCA polygons where grow zone = 1 and acres > 50. Select from REGNET all polygons that have their center in the selected RUCA polygons. Export as Urban_Core.
14. Select all RUCA polygons where grow zone = 2 and acres > 50. Select from REGNET all polygons that have their center in the selected RUCA polygons. Export as Urban_Commute.
15. Select all RUCA polygons where grow zone = 3 and acres > 50. Select from REGNET all polygons that have their center in the selected RUCA polygons. Export as Rural.
16. Add an attribute to REGNET called LogCNVRT90_00. Select by attribute from REGNET where CNVRT90_00 > 0. Calculate the log: LogCNVRT90_00 = log (CNVRT90_00 + .0001).
17. In SAS, run PROC UNIVARIATE / CLM / PROC MEAN to calculate the significant STD on each rural, urban and urban commute attribute table at p < .05, SE = 1.64. This provides the statistically significant values are related to the upper and lower limits:

SE = (upper CL – Mean) / STD

18. Use calculated Upper CL from SAS PROC MEANS (alpha = .10, upper one tail test p<.05, SE = 1.64) to select out from Urban_Core, Urban_Commute and Rural where LogCNVRT90_00 = Upper CL:
    - Select by Attribute from Urban_Core where LogCNVRT90_00 >= 2.6343854. Export as hspots_core.
    - Select by Attribute from Urban_Commute where LogCNVRT90_00 >= 1.677184. Export as hspots_commute.
    - Select by Attribute from Rural where LogCNVRT90_00 >= 1.0177744. Export as hspots_rural.
17. Merge impervious surface hotspots and urban hotspots to create hotspots_1. Ran a UNION in ArcToolbox - hspots_imp + hspots_core = hspots_1.
18. Merge impervious surface hotspots and urban commute hotspots to create hspots_2. Ran a UNION in ArcToolbox - hspots_imp + hspots_commute = hspots_2.
19. Merge impervious surface hotspots and rural hotspots to create hotspots_3. Ran a UNION in ArcToolbox - hspots_imp + hspots_rural = hspots_3.
20. Converted each feature class to a grid:
    a. In ArcMap, calculated ID_1 = 1. Set snap environment to RESAC. Convert to a grid:

       Field: ID_1
       Output cell size: 30 meter
       Output raster: hspots_1, hspots_2, hspots_3

Threat Grids

Travel Time

Creating a travel time grid to incorporate the influence of distance to hot spots on surrounding areas.

1. Download Tiger Roads data. Added an attribute called RDS_TTIME (Long Integer). Calculated travel time based on CFCC codes and RLA methodology:

CFCC	Description	MPH	TTIME (minutes per meter * 100K)
A1	Primary highway with limited access (e.g., Interstates)	65	57
A2	Primary road without limited access (mainly US Highways)	55	68
A3	Secondary and connecting roads (e.g., State and County highways)	40	93
A4	Local, neighborhood, and rural roads	30	124
A6	Road with special characteristics (ramps, traffic circles, etc.)	15	249
Other	A5x's and A7x's (off-road trails, driveways, alleys, etc.)	5	746

65 * 1.60934 = 104.6 kph * 1000/60 = 1743 meters per minute, 1/1743 = 0.000574 minutes per meter

2. Convert tiger roads to a grid in ArcMap (Spatial Analyst → Features to Raster):

   Field: rds_ttime
   Output cell size: 30 meter
   Output raster: RDS_TTIME2
3. Change NoData values in TTIME to 746 (consider off road travel per RLA):

   Grid: |> setwindow resac <|
   Grid: |> setwindow resac resac <|
   Grid: |> rds_ttime2 = con (isnull (rds_ttime), 746, rds_ttime2) <|
4. Calculate the urban growth treat grid based on travel time to nearest hot spot:

   Grid: |> setwindow resac resac <|
   Grid: |> setcell resac <|
   Grid: |> threat_1 = int(costdistance(hspots_1, rds_ttime2)) <|
5. Calculate urban fringe / metropolitan fringe growth threat based on travel time:

   Grid: |> setwindow resac resac <|
   Grid: |> setcell resac <|

Grid: |> threat_2 = int(costdistance(hspots_2, rds_ttime2)) <|

6. Calculate outside the urban fringe growth threat based on travel time:

Grid: |> setwindow resac resac <|
Grid: |> setcell resac <|
Grid: |> threat_3 = int(costdistance(hspots_3, rds_ttime2)) <|

Threat

1. Multiply each grid by .33 to get a proportional value of threat / travel time in order to generate a summed threat grid of all three layers:

Grid: |> threat1_x33 = threat_1 * .33 <|
Grid: |> threat2_x33 = threat_2 * .33 <|
Grid: |> threat3_x33 = threat_3 * .33 <|

2. Set NODATA values to 0 to sum layers:

Grid: |> threat1_x33_0 = con(isnull(threat1_x33), 0, threat1_x33) <|
Grid: |> threat2_x33_0 = con(isnull(threat2_x33), 0, threat2_x33) <|
Grid: |> threat3_x33_0 = con(isnull(threat3_x33), 0, threat3_x33) <|

3. Sum threat layers together to generate a threat_sum grid showing an integrated threat grid:

Grid: |> setwindow resac resac <|
Grid: |> setcell resac <|
Grid: |> threat_sum = sum(threat1_x33_0, threat2_x33_0, threat3_x33_0) <|

4. Display threat_1 (urban growth threat), threat_2 (urban fringe growth) and urban_3 (outside the urban fringe growth) with 5 manual breaks in ArcMap, with a higher threat value indicates a great threat:

THREAT	GRID VALUE	TRAVEL TIME (minutes)
5	0	0
4	0.001 - 1,500,000	0 to 15
3	1,500,000.001 - 3,000,000	15 to 30
2	3,000,000.001 - 6,000,000	30 to 60
1	6,000,000.001 - 12,000,000	60 to 120

5. Display threat_sum (compiled threat model showing predicted growth in the urban, urban fringe and outside the urban fringe areas with 8 manual breaks in ArcMap (higher threat value indicates a greater growth threat):

THREAT	GRID VALUE	TRAVEL TIME (approx minutes)
8	0 – 1,000,000	0 to 10
7	> 1,000,000 – 2,000,000	10 to 20
6	> 2,000,000 – 3,000,000	20 to 30
5	> 3,000,000 – 4,000,000	30 to 40
4	> 4,000,000 – 5,000,000	40 to 50
3	> 5,000,000 – 6,000,000	50 to 60
2	> 6,000,000 – 9,000,000	60 to 90
1	> 9,000,000	> 90

The gradient is spread at smaller increments on the threat_sum grid because it proportionally reduced the original number to add into the final grid. .

6. Set threat grid values to numbers based on threat defined above in GRID.

For threat_1, threat_2 and threat_3 grids:

Grid: |> threat1_xx = con(threat_xx = = 0, 5, con(threat_xx > 0, con(threat_xx < = 1500000, 4, con(threat_xx > 1500000, con (threat_xx < = 3000000, 3, con(threat_xx > 3000000, con(threat_xx < = 6000000, 2, 1))))))) <|

For threat_all:

thrt_all= con(thrtall_va <= 1000000, 8, con(thrtall_va > 1000000, con(thrtall_va <= 2000000, 7, con(thrtall_va > 2000000, con(thrtall_va <= 3000000, 6, con(thrtall_va > 3000000, con(thrtall_va <= 4000000, 5, con(thrtall_va > 4000000, con(thrtall_va <= 5000000, 4, con(thrtall_va > 5000000, con(thrtall_va <= 6000000, 3, con(thrtall_va > 6000000, con(thrtall_va <= 9000000, 2, 1)))))))))))) <|

7. Convert grids to a shapefile.
8. Generate metadata in ArcCatalog.
9. Convert shapefile to geodatabase feature classes.
10. Topology:
    a. Created a topology for UrbanGrowthThreat, UrbanFringeGrowthThreat, GrowthOutsidetheUrbanFringeThreat and VulnerabilityModel_AllThreat feature classes for the following rules:
        i. Must Not Overlap
        ii. Must Not Have Gaps
    b. Validated topology and cleaned where necessary.

Model Validation

The original version of the Vulnerability Model was sent to:

- Crater PDC
- Hampton Roads PDC
- Goochland County
- Middle Peninsula PDC
- Northern Neck PDC
- Thomas Jefferson PDC

Comments indicated the model was representing too much land as being hotspots or heavily weighted to indicate potential growth.

The model was re-run with statistical analyses to pick out values representing statistically significant hotspot values. Four models were developed instead of one overall vulnerability model to account for urban, suburban and rural growth pressures as individual issues, instead of compiling into one overall model. The data was becoming lost in over-generalization of values in order to develop a single model.

The final model was passed through an internal review at the Division of Natural Heritage.

The revised Vulnerability model was validated in house. Comments from the version 1 validation were applied to the model.

The VCLNA website will be equipped to receive comments regarding the Vulnerability model results. These comments will be reviewed and assessed in relation to the model; this will enable a continuing evaluation of the model. The Vulnerability Models represent prediction models, ground truthing hotspots at this point in time may not prove ineffective as the model projects out ten + years in time.

Discussion

The Vulnerability Model naming convention reflects U.S. Census designations and can be translated as the following:

- Urban Growth Prediction – Shows predicted urban growth patterns in Virginia.
- Urban Fringe Growth Prediction – Shows predicted suburban growth patters in Virginia. Suburban growth is defined as growth occurring in suburban designated areas. These areas are typically at the fringe or edge of urban growth and represent less dense growth than found in traditional urban settings.

- Growth Outside the Urban Fringe – Shows predicted rural growth patterns in Virginia. Rural growth is defined as growth in rural designated areas (i.e. larger lot size).

Model 2 Refinements

This version of the Vulnerability Model used more parcel data in the development of the regression model. The model was refined for a closer fit to the structure of the data. This can be seen in the hotspot analysis. The previous version of the model had hotspots located across Virginia, without a great deal of structure, reflecting noise in the data and potential over-representation of hotspots. Refinement of the SAS methodology allowed for tighter clusters of hotspots, reflecting a more accurate portrayal of landscape growth patterns. This can be seen in the number of hotspots identified during the two analyses:

Layer	***Version 1 Count***	***Version 2 Count***
hotspots 1	6135	2797
hotspots 2	11681	8916
hotspots 3	12798	9673

FUTURE APPLICATIONS

Additional Data Incorporation

Development of a statewide model constrains the model to available statewide datasets. The Vulnerability Model serves as a base growth prediction model developed on a ten year increment of data, projecting out to approximately ten years and more into the future. It is important for the end user to apply specific datasets as needed to make decisions with the model.

It is difficult to model parameters that influence growth and development, such as politics or economic influences, particularly at a statewide scale. Local knowledge should be applied to the model to assess the growth patterns and influences at a local scale.

Additional datasets that can be applied to the model to assess actual growth versus predicted growth may include:

- Soils data in an attempt to model septic sewer capacity as an influence on growth / development
- Economic development data to identify areas promoted for development, such as enterprise zones.
- Comprehensive plans
- Zoning information

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Claggett, P. R. and C. Bisland. 2004. Assessing the vulnerability of forests and farmlands to development in the Chesapeake Bay Watershed. Proceedings of the IASTED International Conference Environmental Modeling and Simulation, 22-24 November 2004, St. Thomas, US Virgin Islands.

Claggett, P. R., Jantz, C. A., Goetz, S. J., and C. Bisland. 2004. Assessing development pressure in the Chesapeake Bay Watershed: An evaluation of two land-use change models. *Environmental Monitoring and Assessment* 94: 129-146.

Goetz S. J., Jantz C. A., Prince S. D., Smith A. J., Wright R. & Varlyguin D. (2004) Integrated analysis of ecosystem interactions with land use change: the Chesapeake Bay watershed. In: Ecosystems and Land Use Change (eds. R. S. DeFries, G. P. Asner & R. A. Houghton) pp. 263-275. American Geophysical Union, Washington DC.

Heimlich, R. E. and W. D. Anderson. 2001. Development at the urban fringe and beyond: impacts on agriculture and rural land. U.S. Department of Agriculture, Agricultural Economic Report 803, Washington, D.C., USA.

RESAC 2000 CBW Impervious Surface Product - Version 1.3. 2000. Mid-Atlantic RESAC, University of Maryland. College Park, MD.

Wilson, E. H. et al. 2003. Development of a geospatial model to quantify, describe and map urban growth. *Remote Sensing of Environment* 82: 275-285.

Table 1. List of cities and counties used in the final regression model.

LOCALITY
Alexandria
Alleghany
Arlington
Charlottesville
Chesterfield
Covington
Emporia
Fairfax City
Fairfax County
Galax
Hampton
Hanover
Harrisonburg
Henrico
Lancaster
Louisa
Madison
New Kent
Newport News
Norton
Pittsylvania
Poquoson
Prince George
Prince William
Radford
Richmond City
Roanoke City
Roanoke County
Salem
Surry
Sussex
VA Beach
Williamsburg
Winchester

Figure 1. PDC 1 LENOWISCO Vulnerability Model.

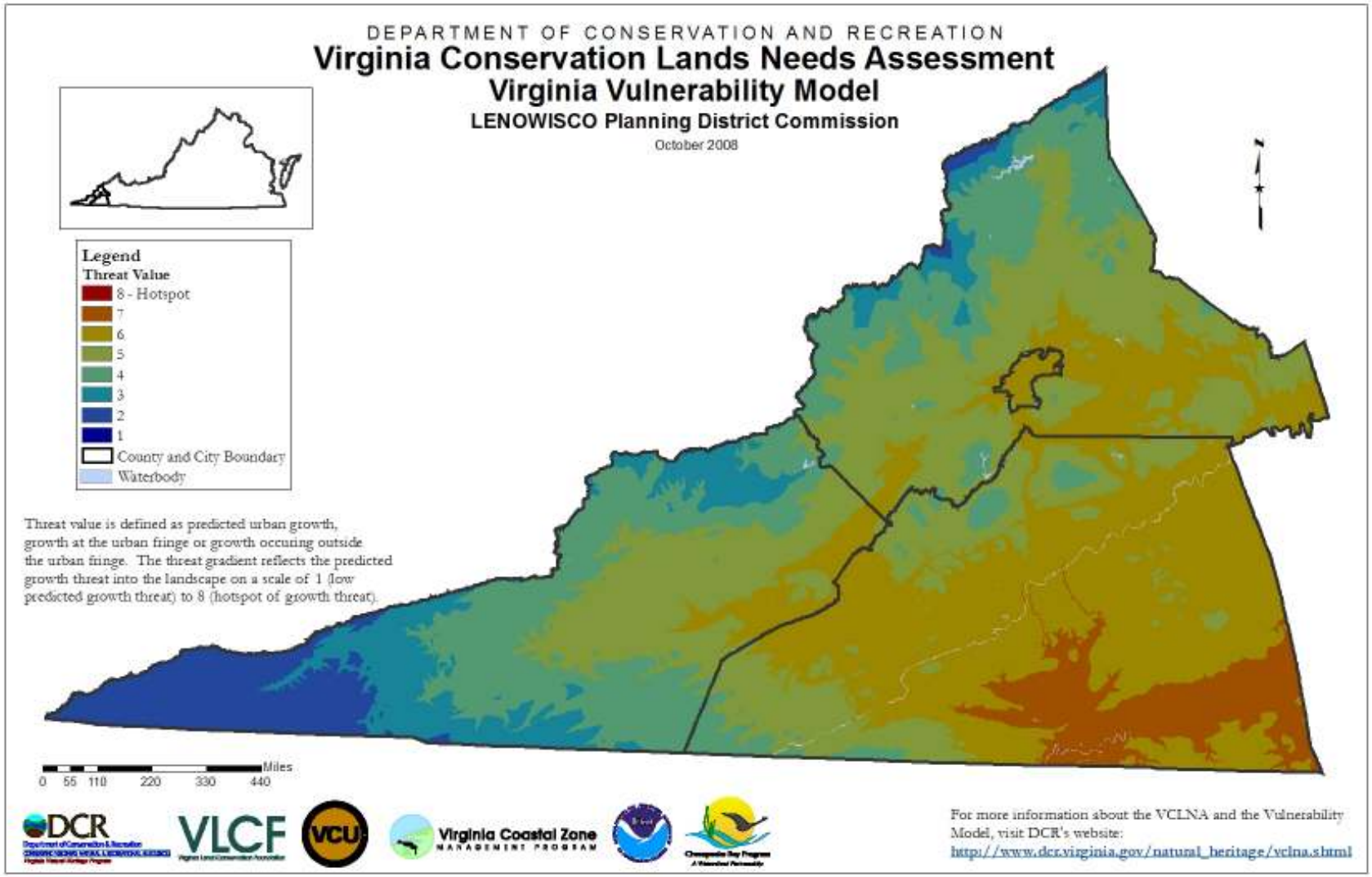


Figure 2. PDC 1 LENOWISCO Urban Vulnerability Model.

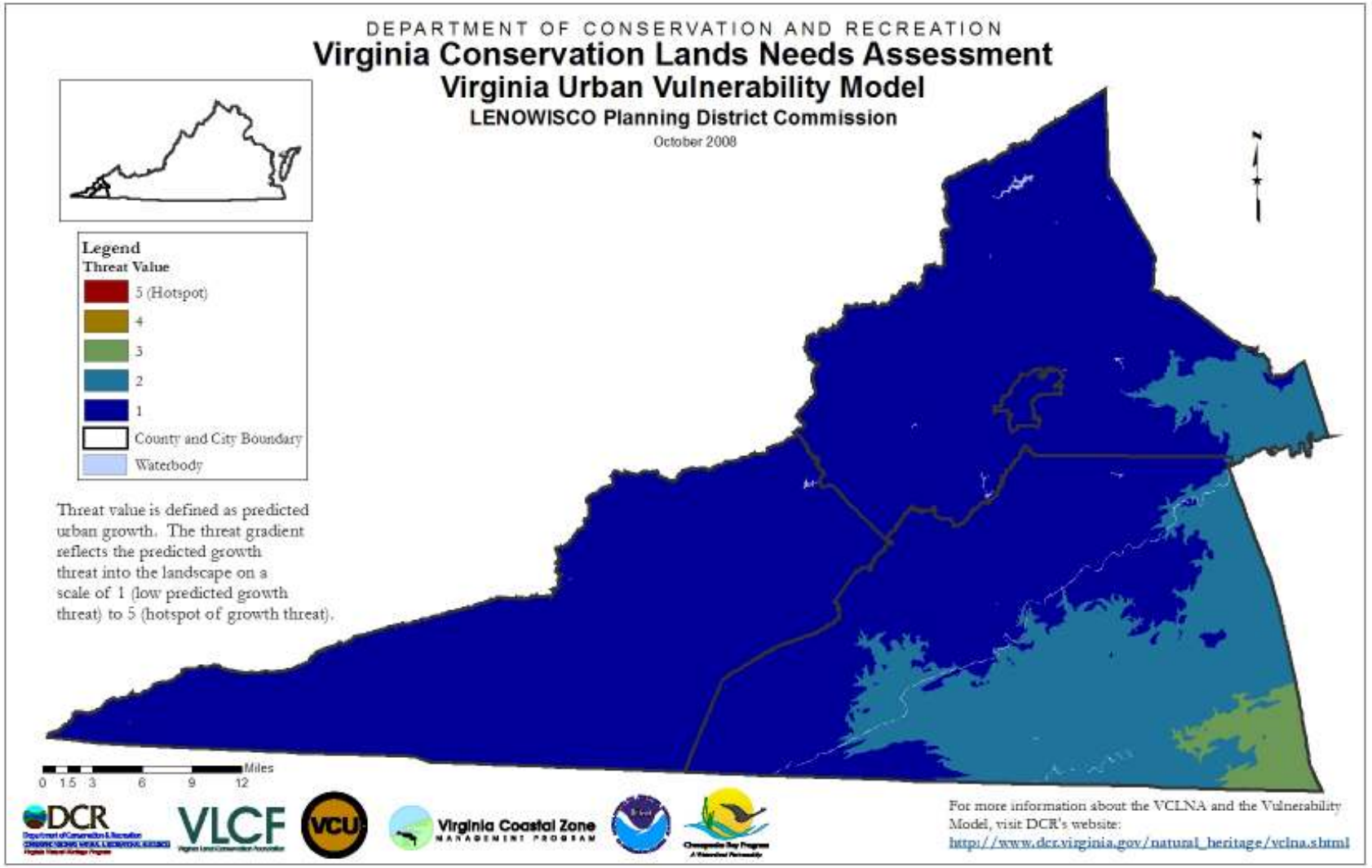


Figure 3. PDC 1 LENOWISCO Urban Fringe Vulnerability Model.

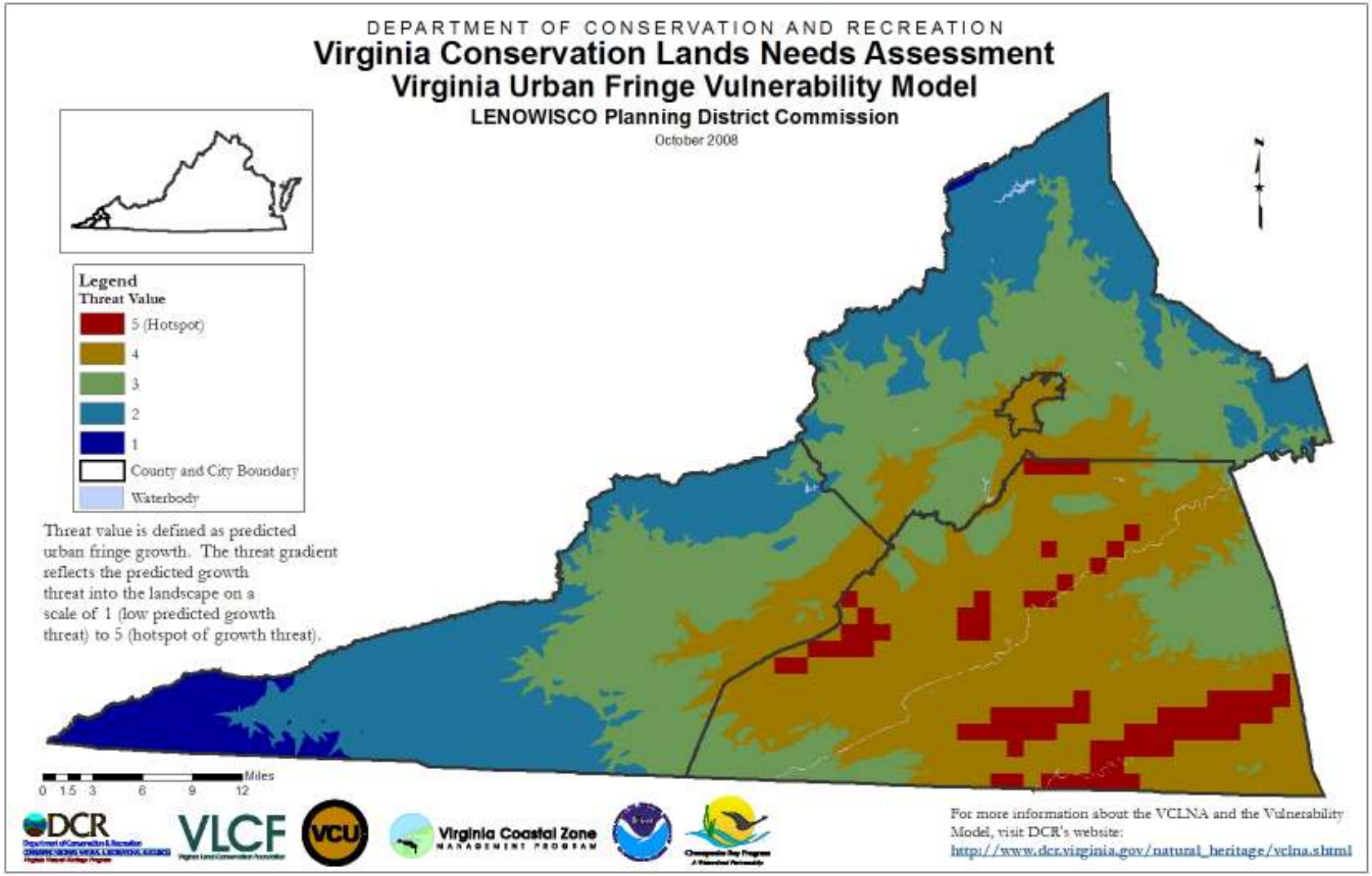


Figure 4. PDC 1 LENOWISCO Outside the Urban Fringe Vulnerability Model.

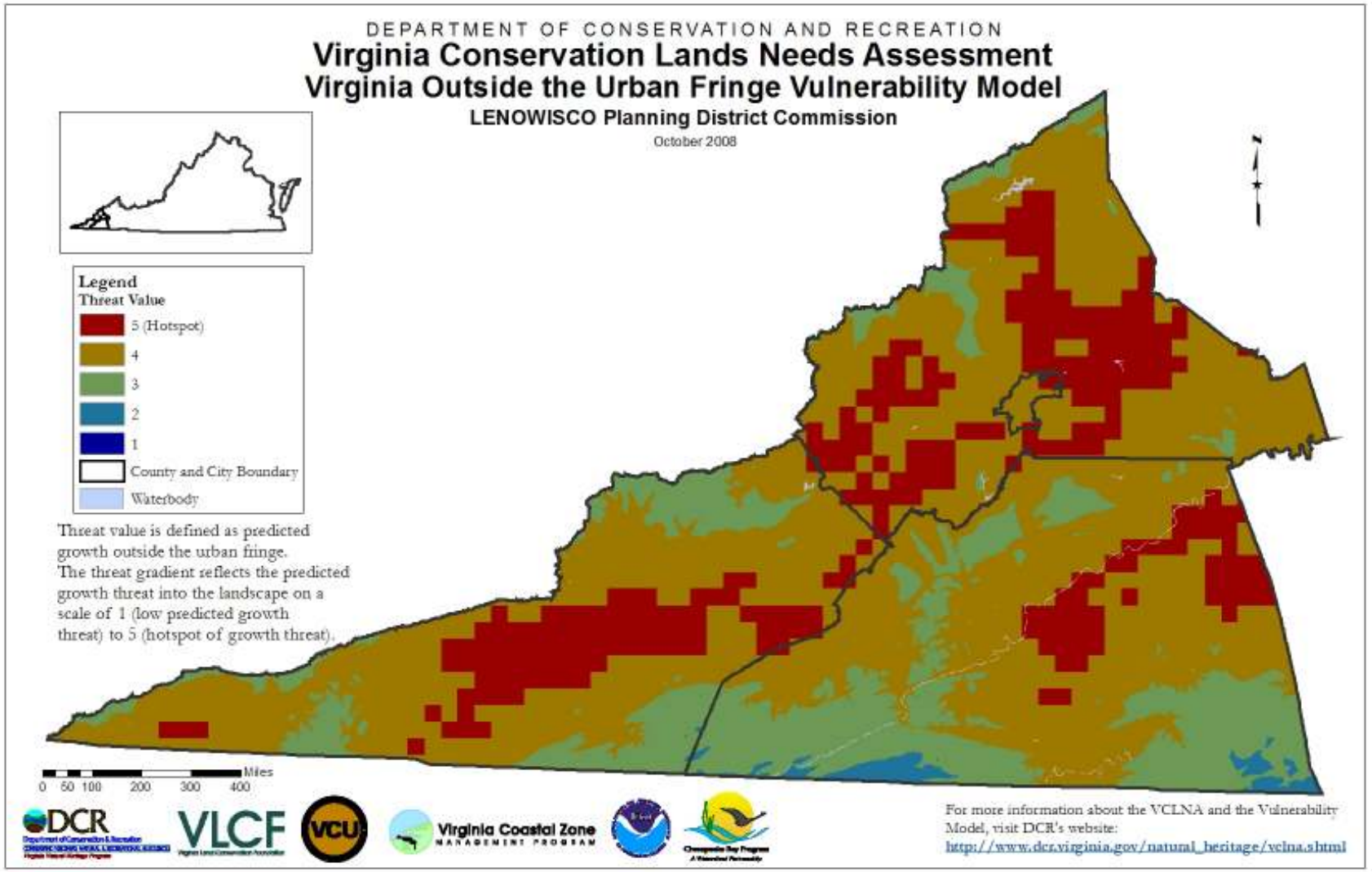


Figure 5. PDC 2 Cumberland Plateau Vulnerability Model.

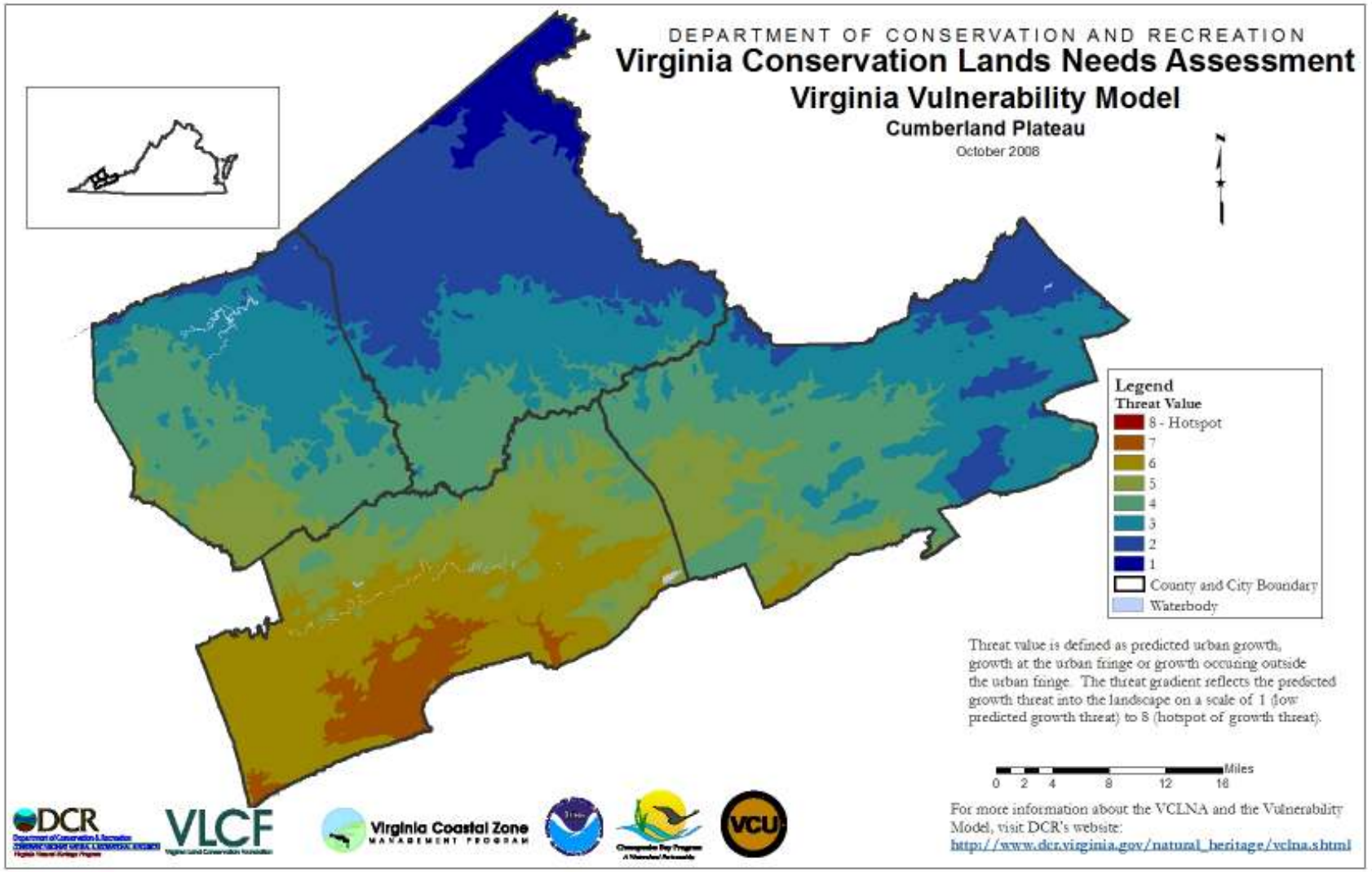


Figure 6. PDC 2 Cumberland Plateau Urban Vulnerability Model.

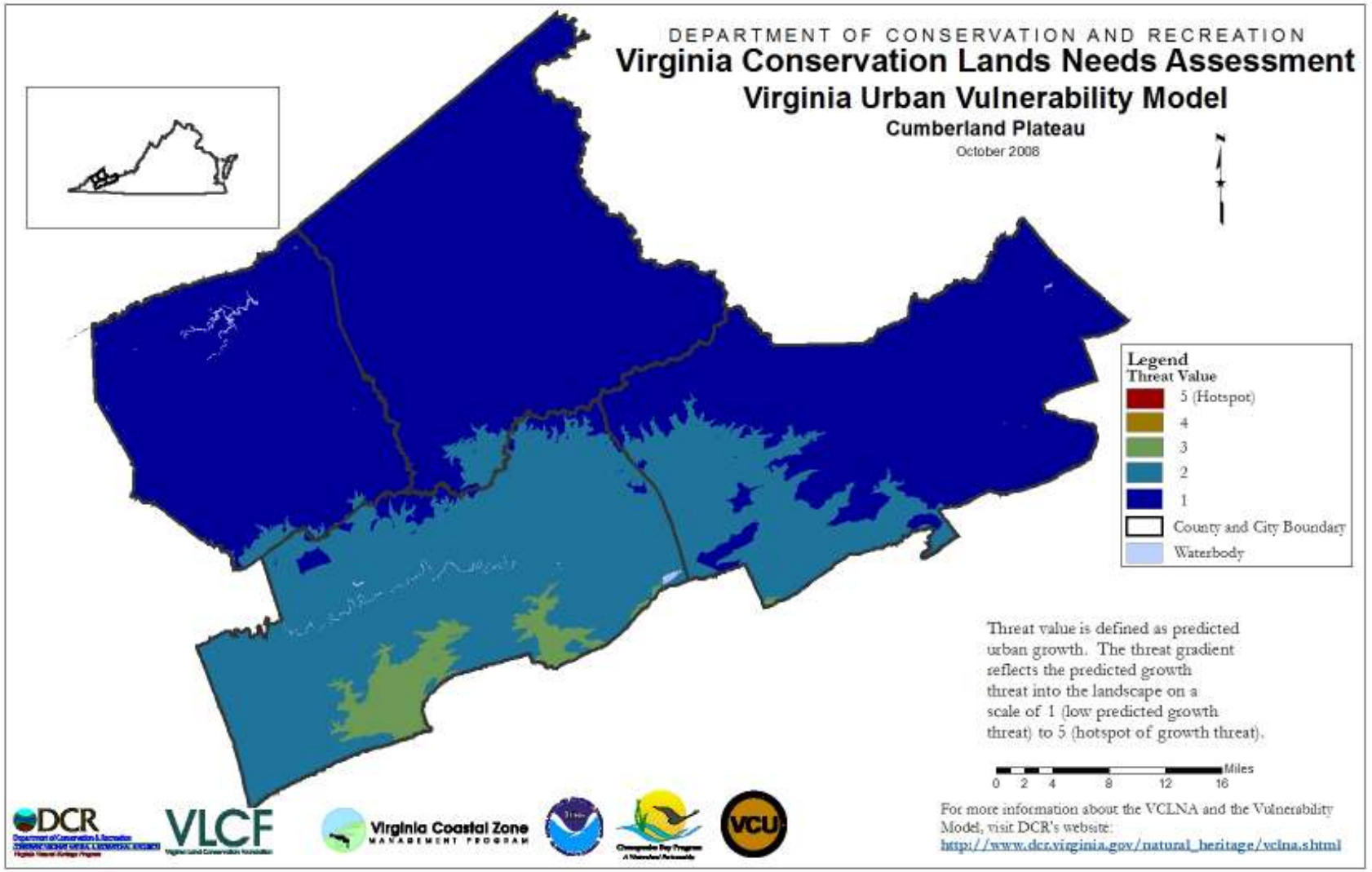


Figure 7. PDC 2 Cumberland Plateau Urban Fringe Vulnerability Model.

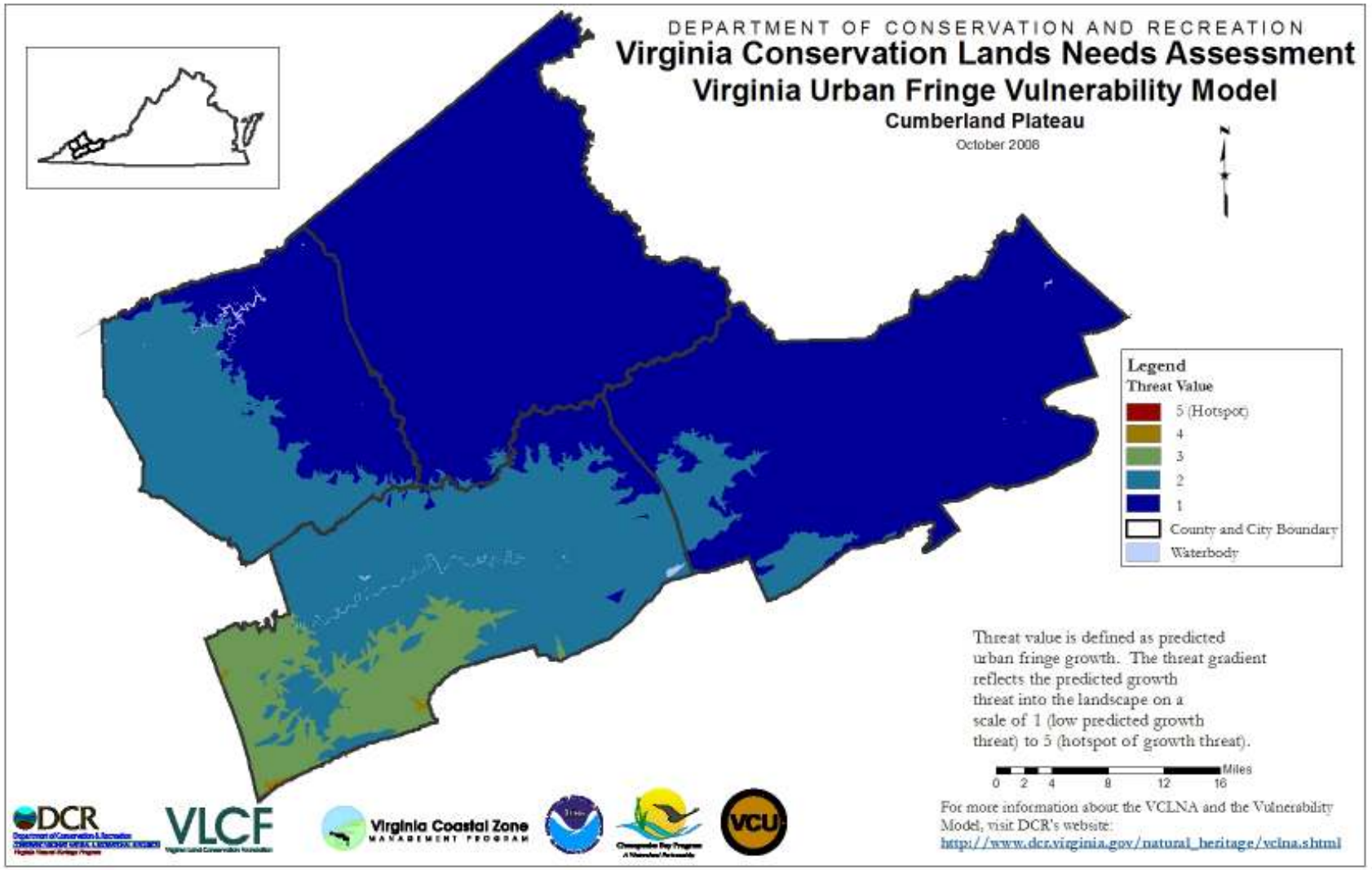


Figure 8. PDC 2 Cumberland Plateau Outside the Urban Fringe Vulnerability Model.

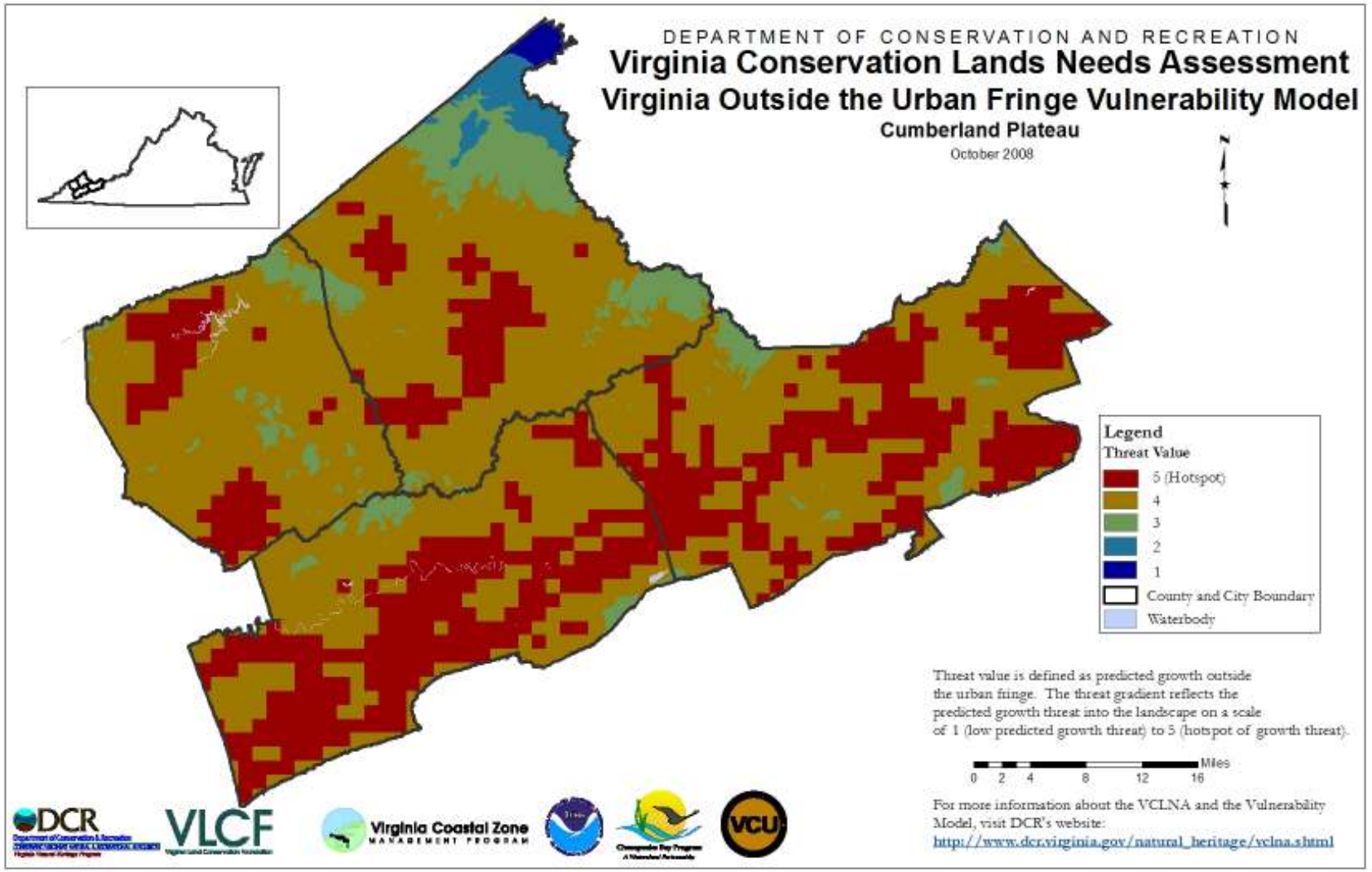


Figure 9. PDC 3 Mount Rogers Vulnerability Model

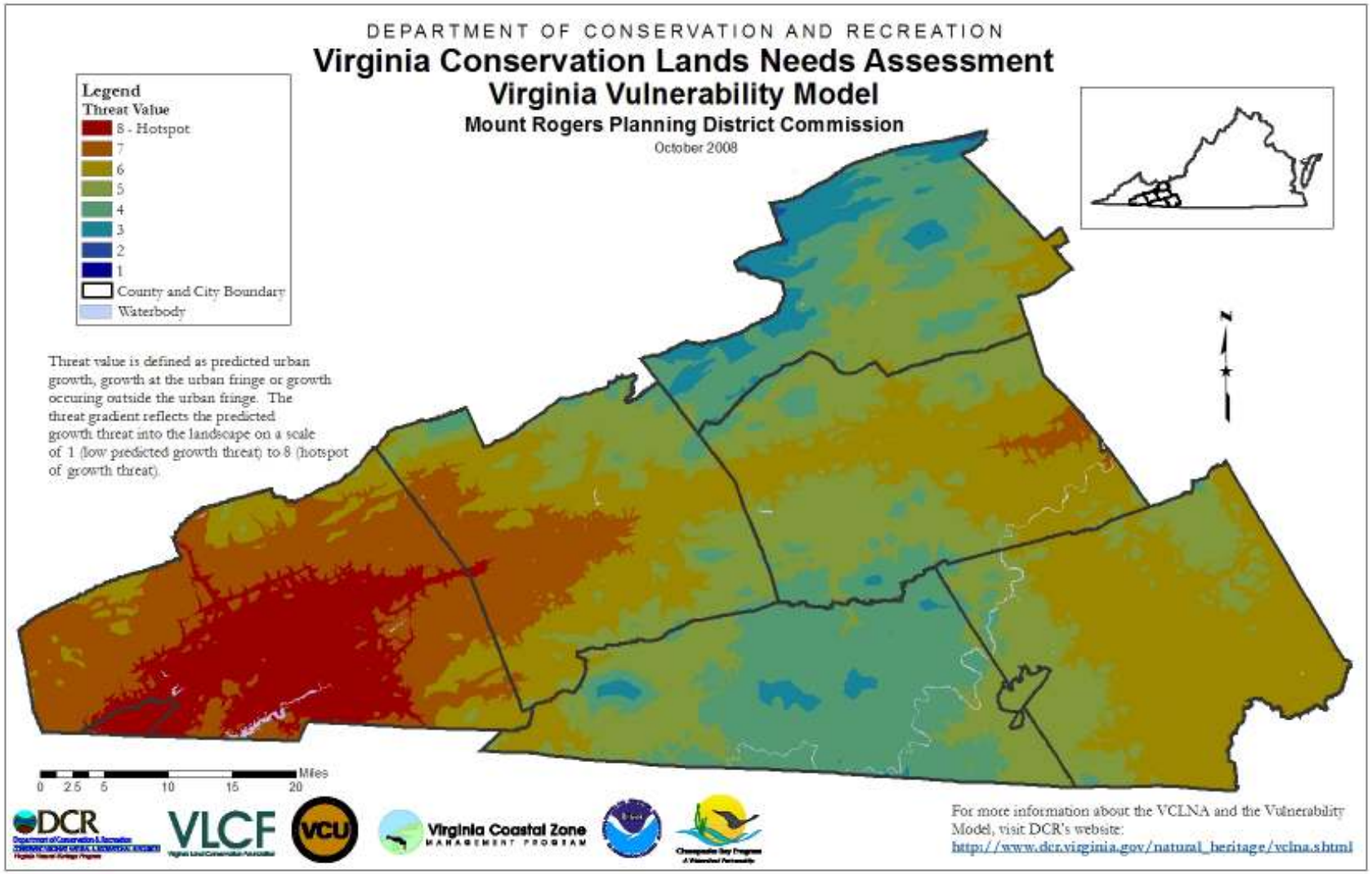


Figure 10. PDC 3 Mount Rogers Urban Vulnerability Model

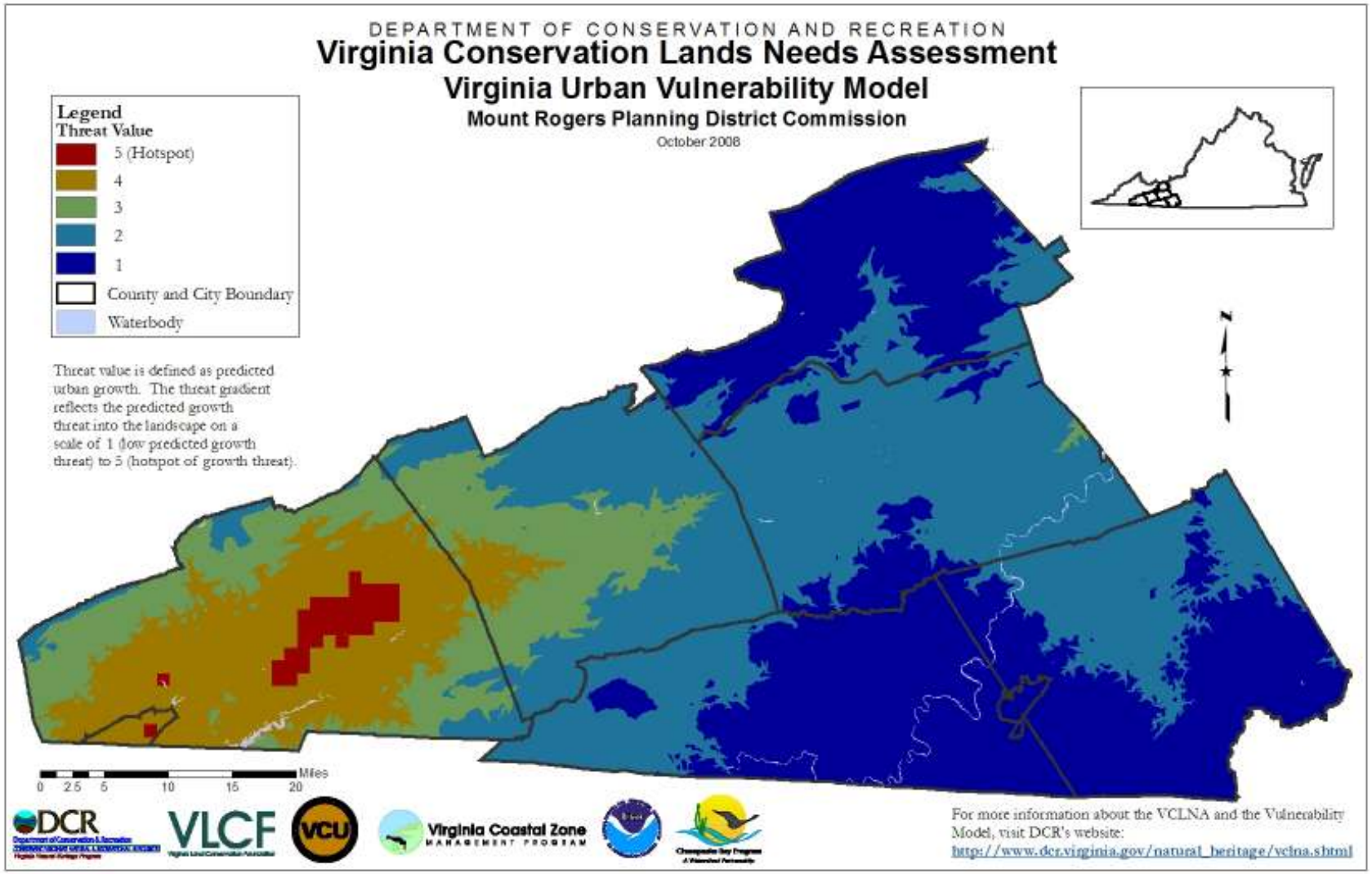


Figure 11. PDC 3 Mount Rogers Urban Fringe Vulnerability Model

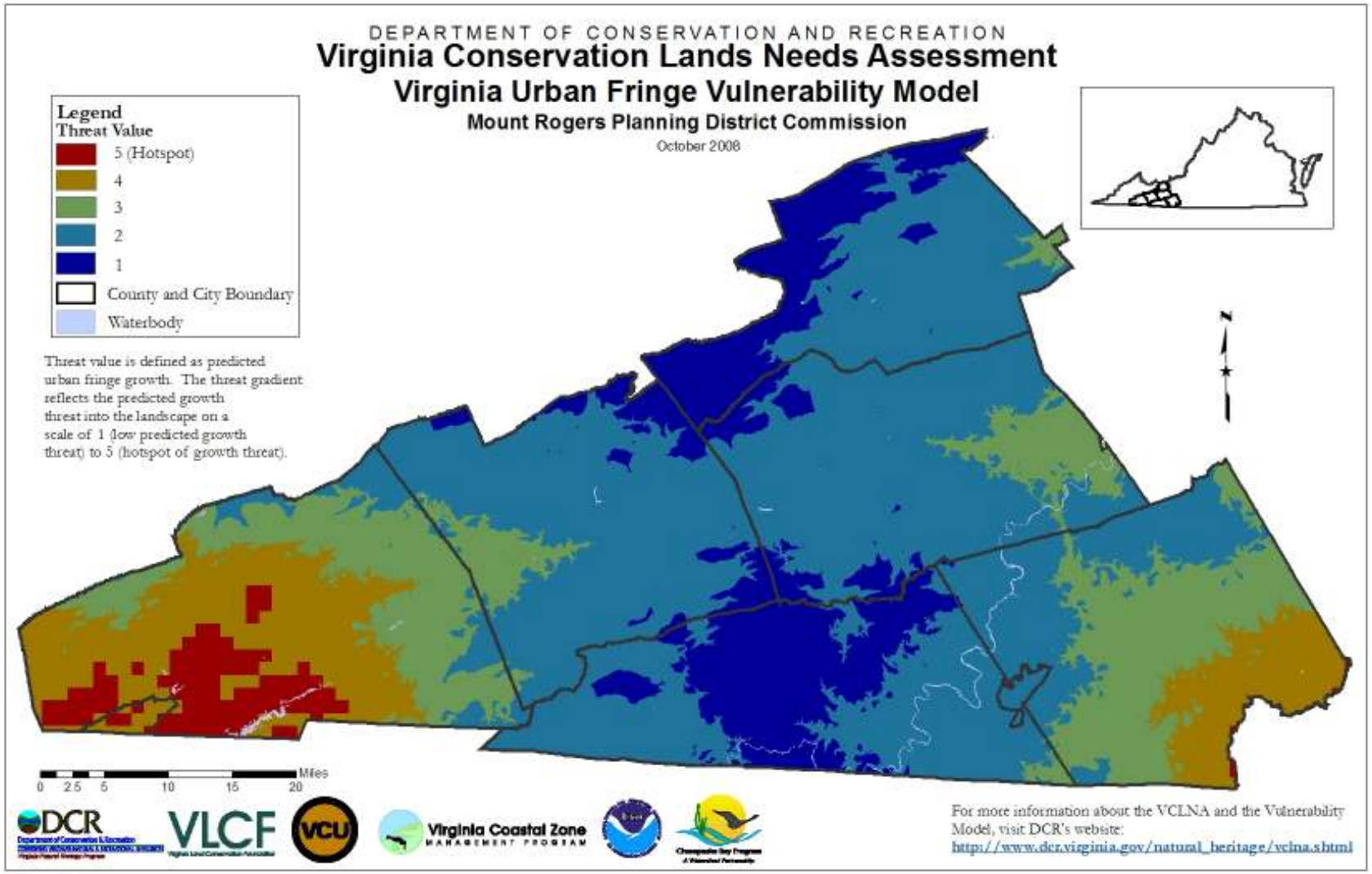


Figure 12. PDC 3 Mount Rogers Growth Outside the Urban Fringe Vulnerability Model

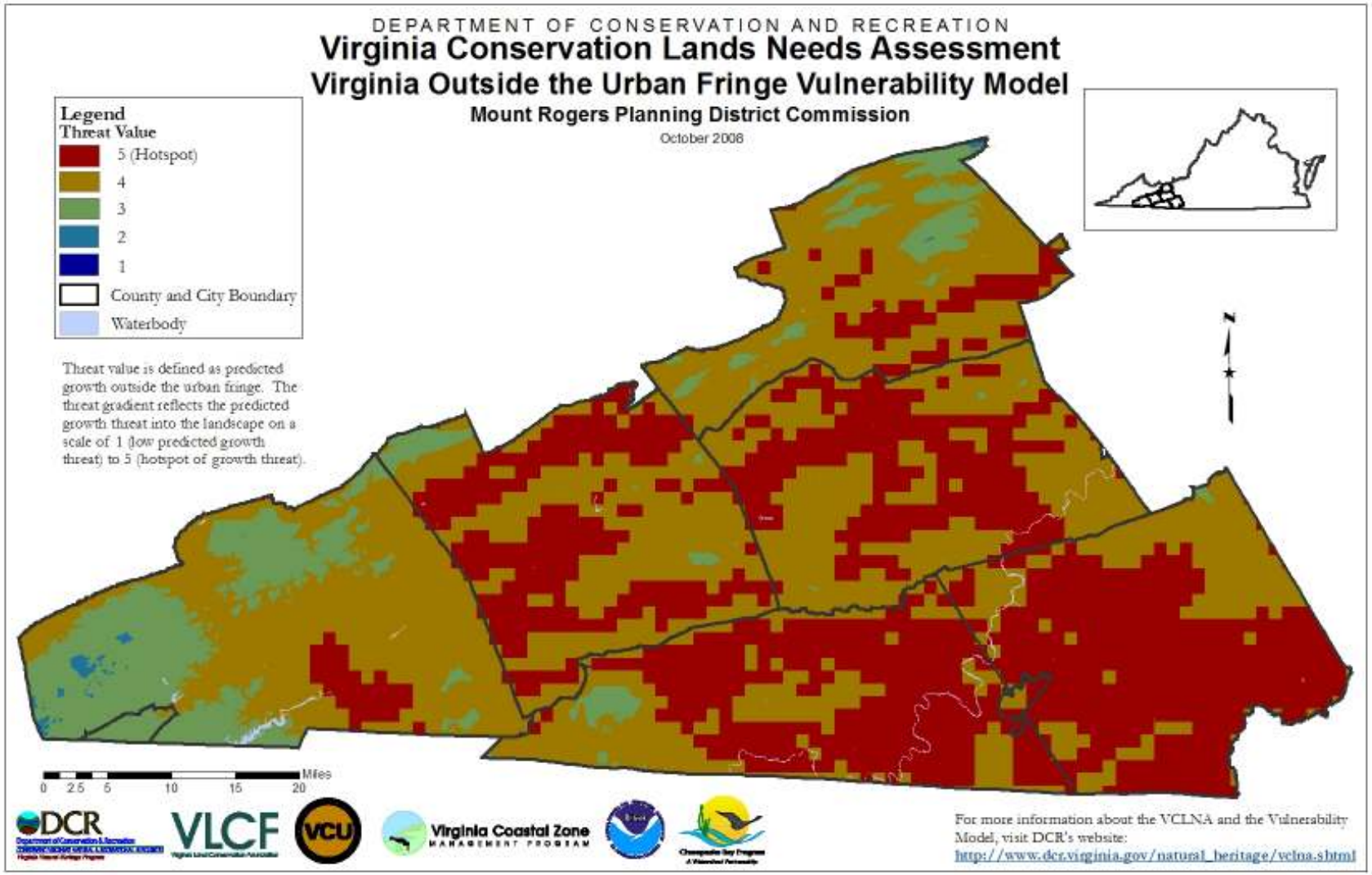


Figure 13. PDC 4 New River Valley Vulnerability Model

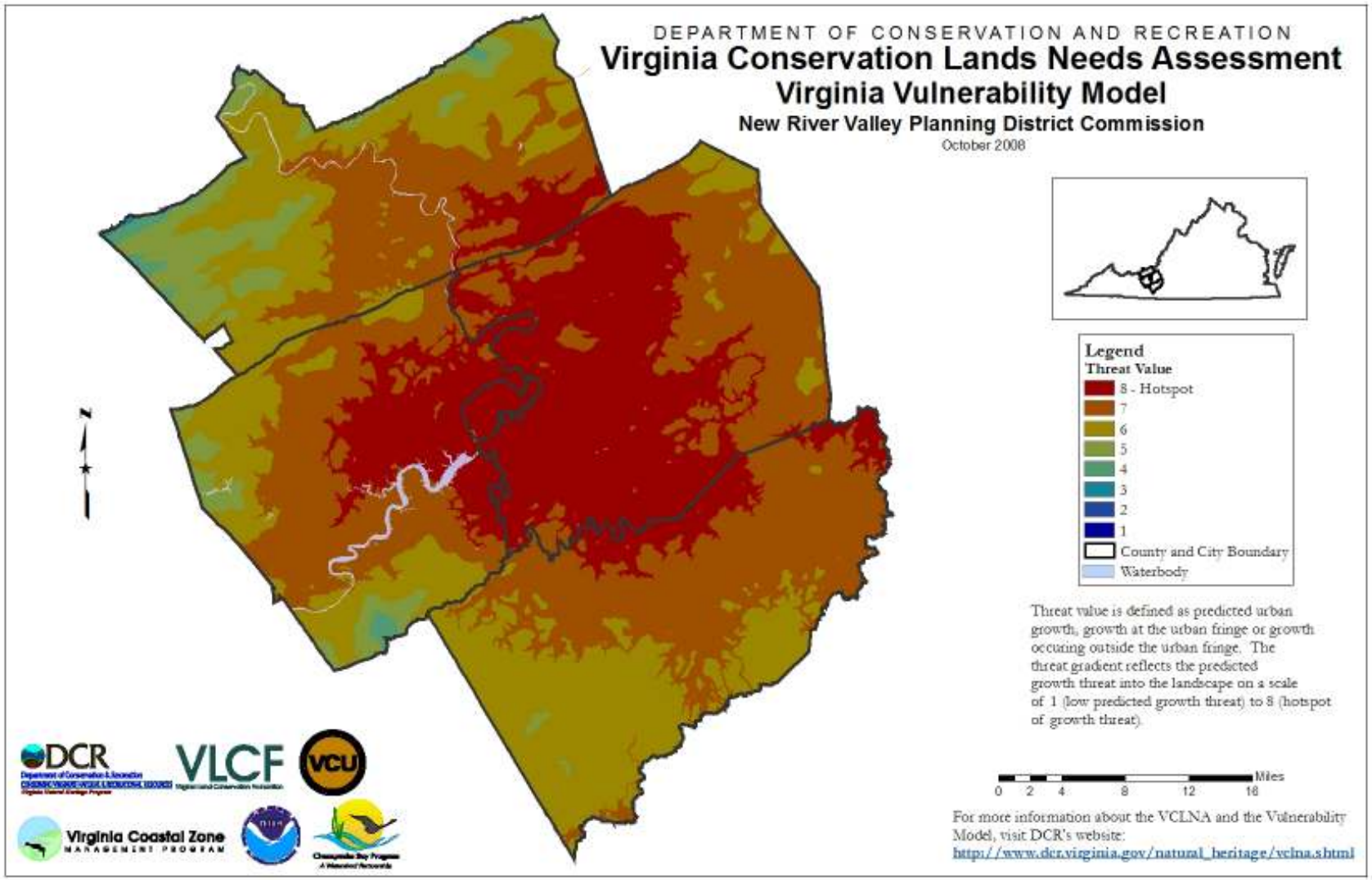


Figure 14. PDC 4 New River Valley Urban Vulnerability Model

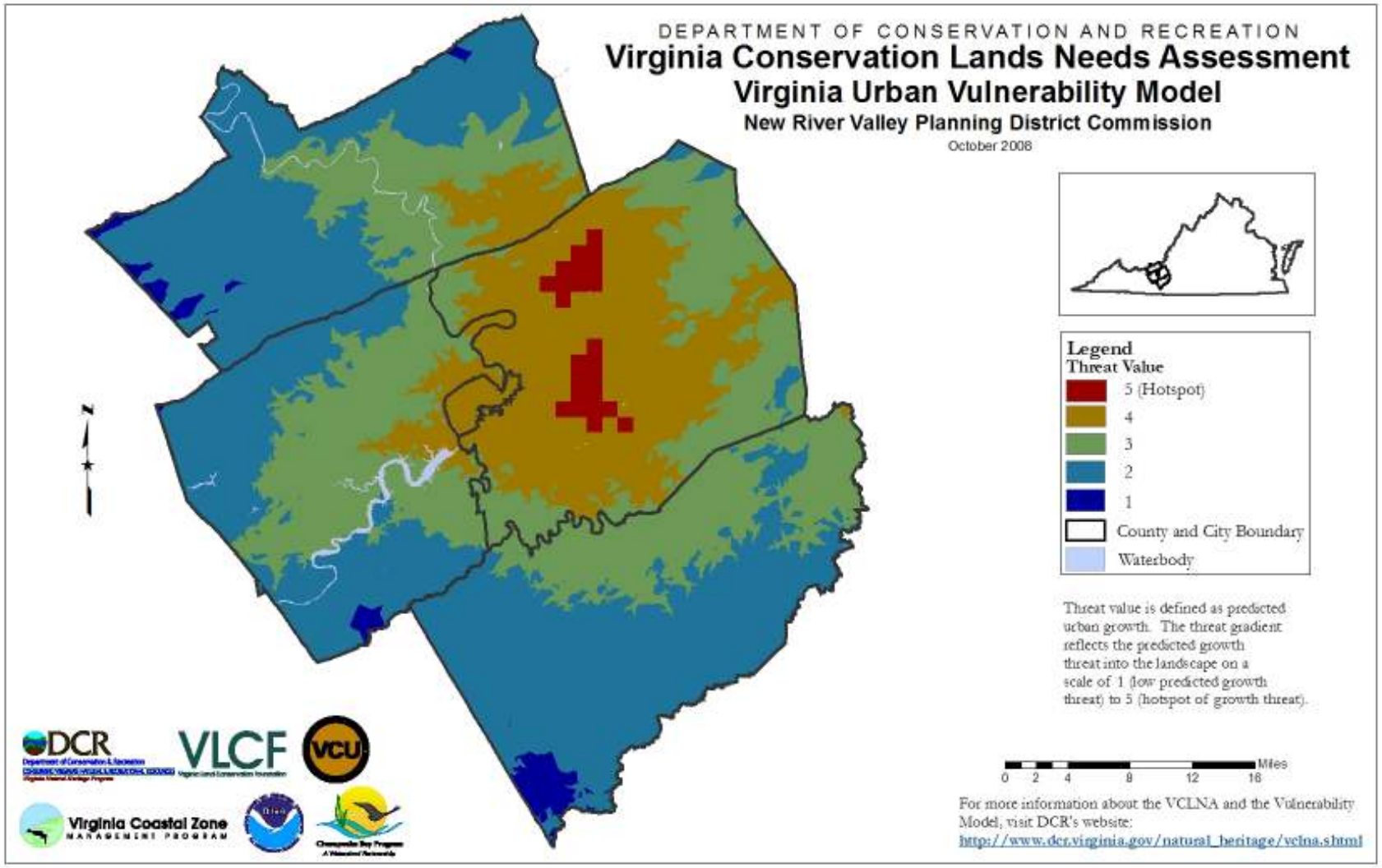


Figure 15. PDC 4 New River Valley Urban Fringe Vulnerability Model

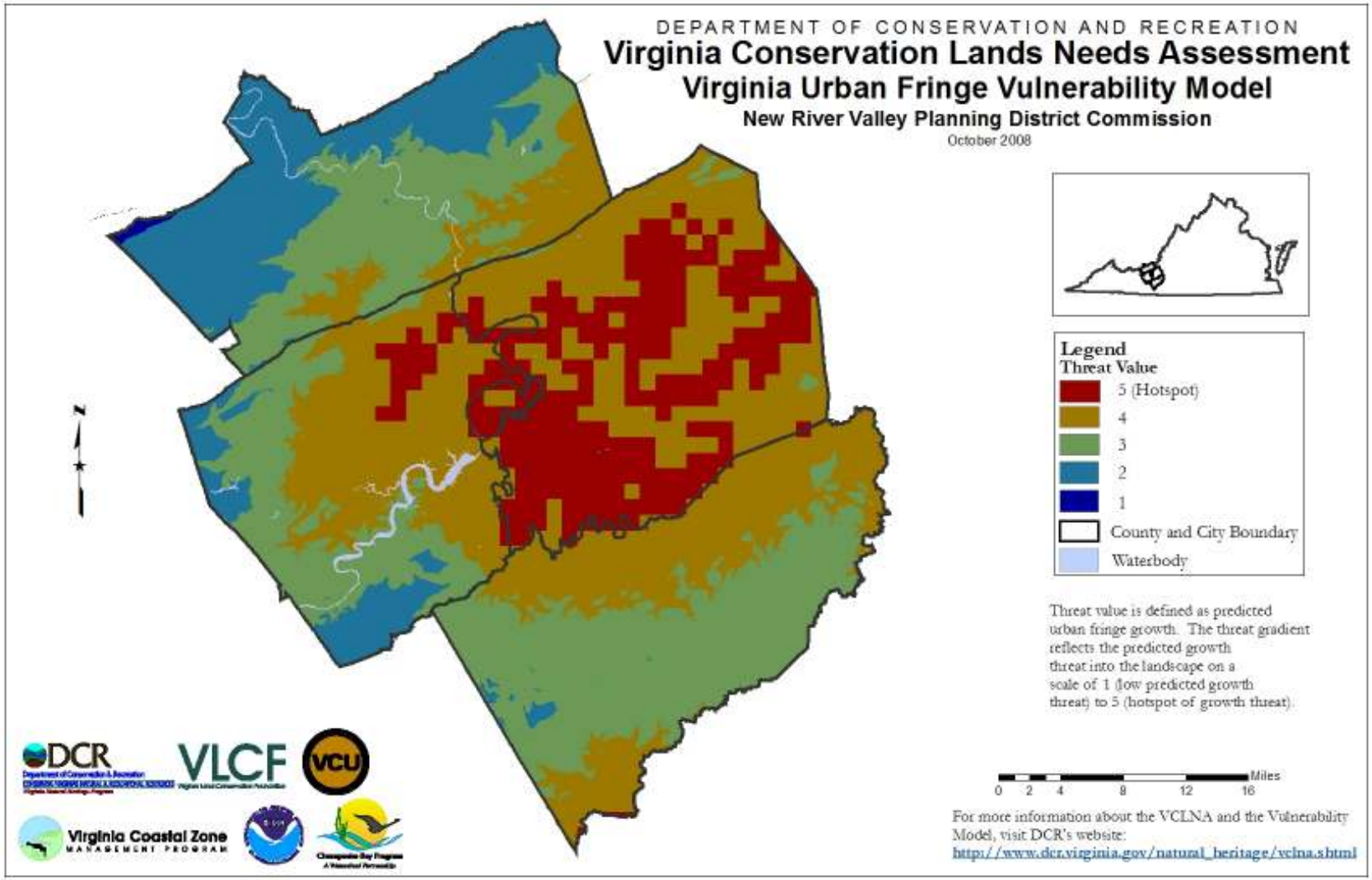


Figure 16. PDC 4 New River Valley Growth Outside the Urban Fringe Vulnerability Model

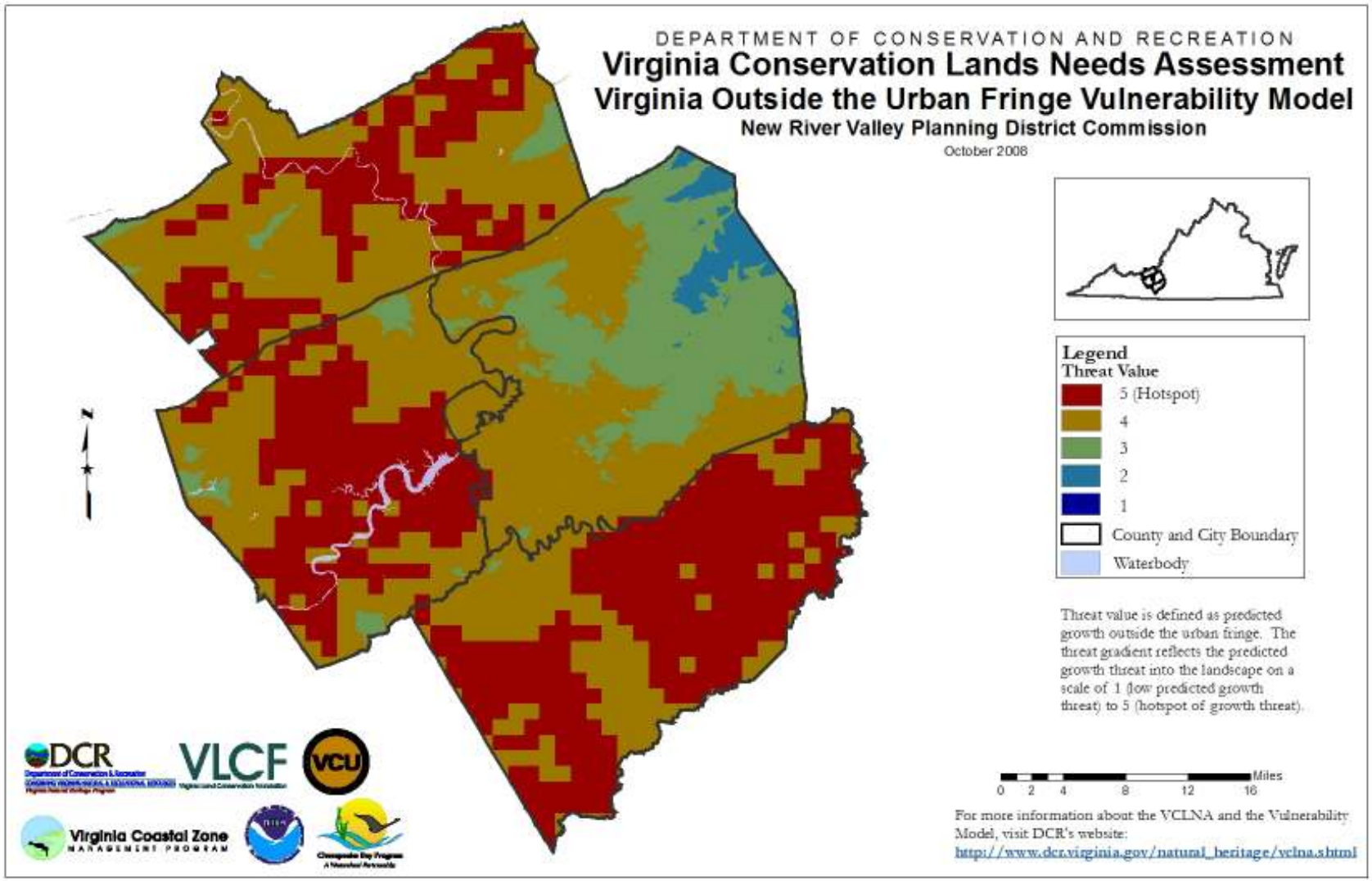


Figure 17. PDC 5 Roanoke Valley-Alleghany Regional Commission Vulnerability Model.

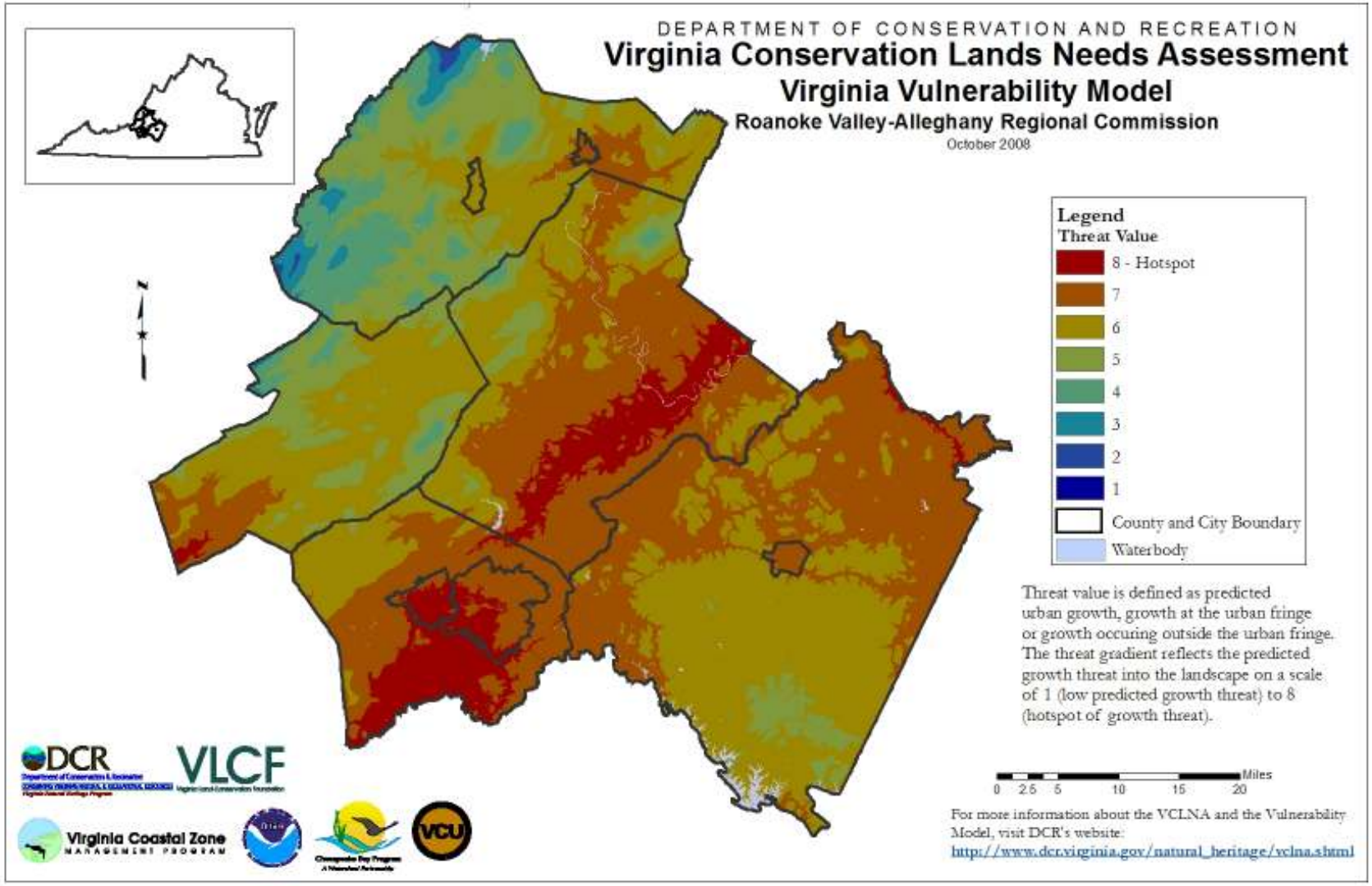


Figure 18. PDC 5 Roanoke Valley-Alleghany Regional Commission Urban Vulnerability Model.

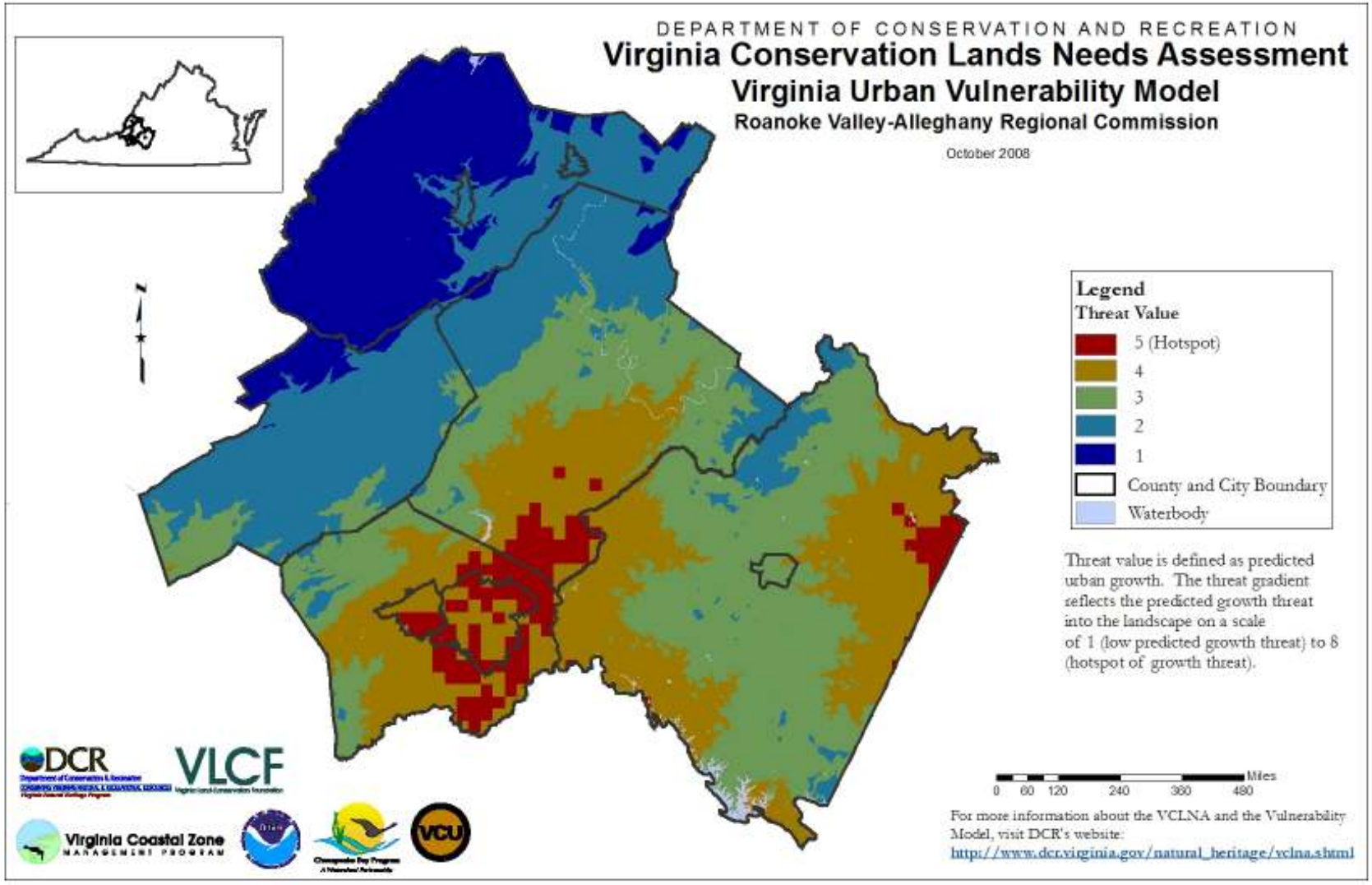


Figure 19. PDC 5 Roanoke Valley-Alleghany Regional Commission Urban Fringe Vulnerability Model.

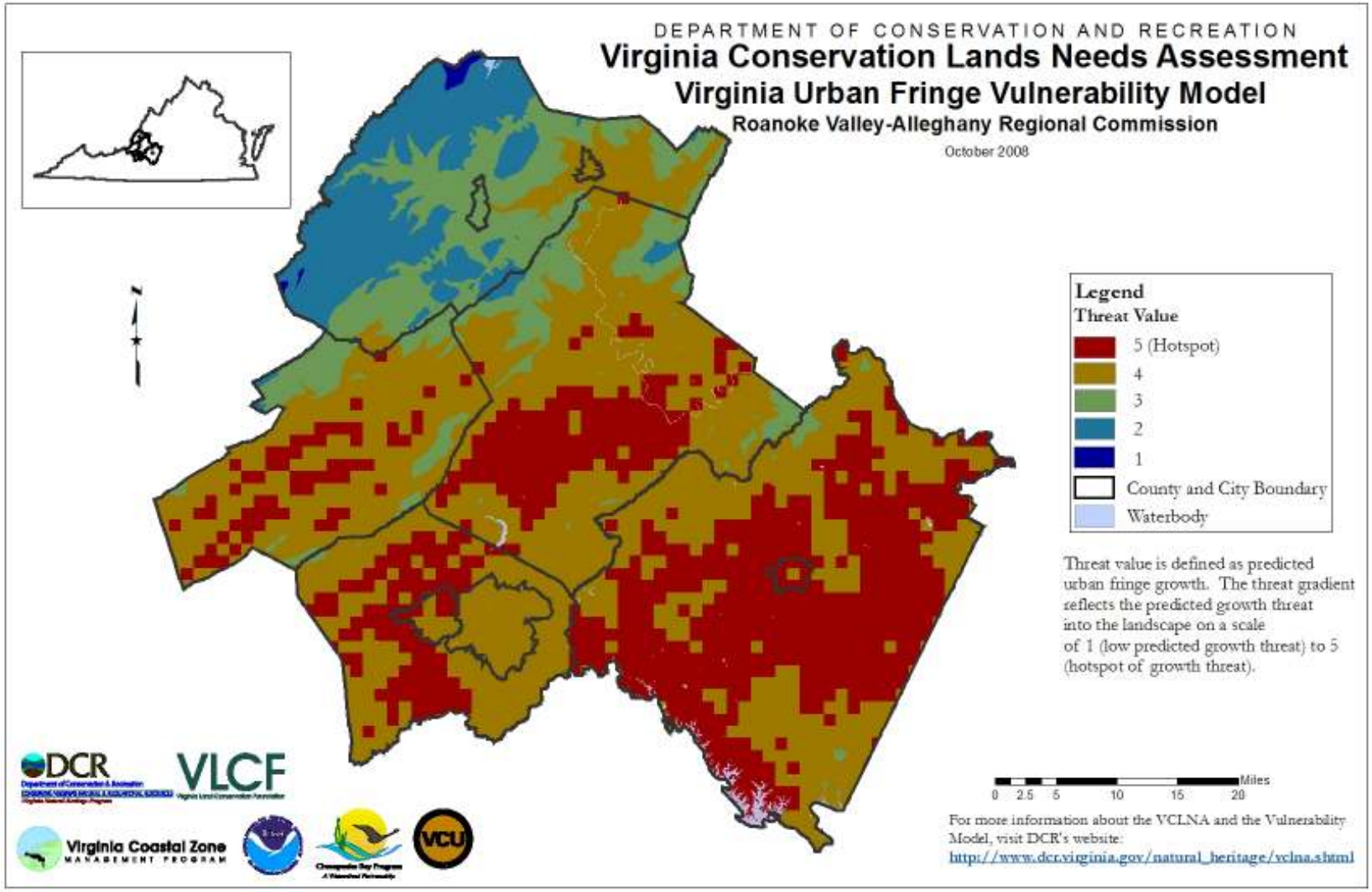


Figure 20. PDC 5 Roanoke Valley-Alleghany Regional Commission Outside the Urban Fringe Vulnerability Model.

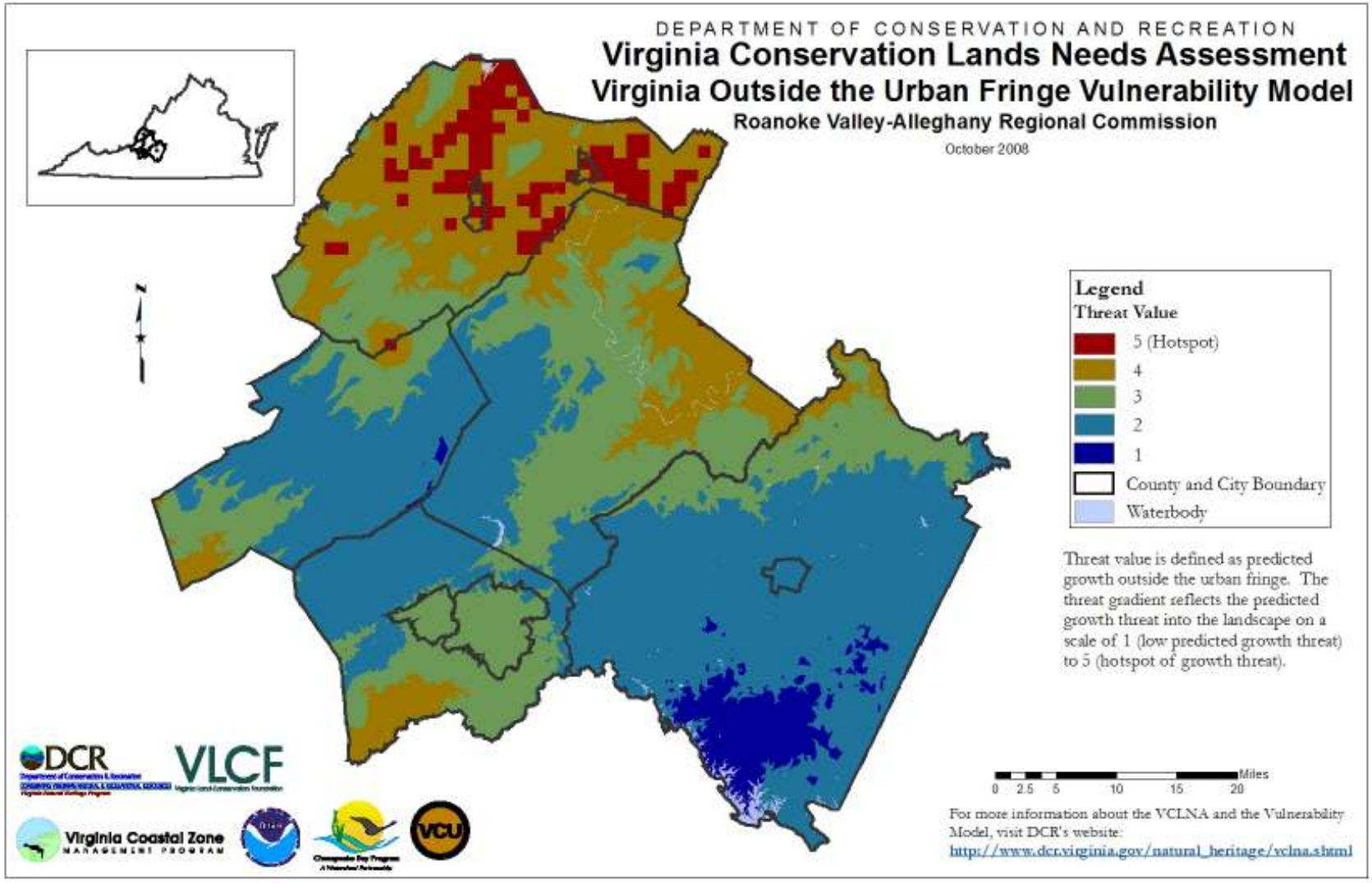


Figure 21. PDC 6 Central Shenandoah Vulnerability Model.

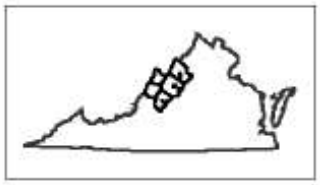
DEPARTMENT OF CONSERVATION AND RECREATION

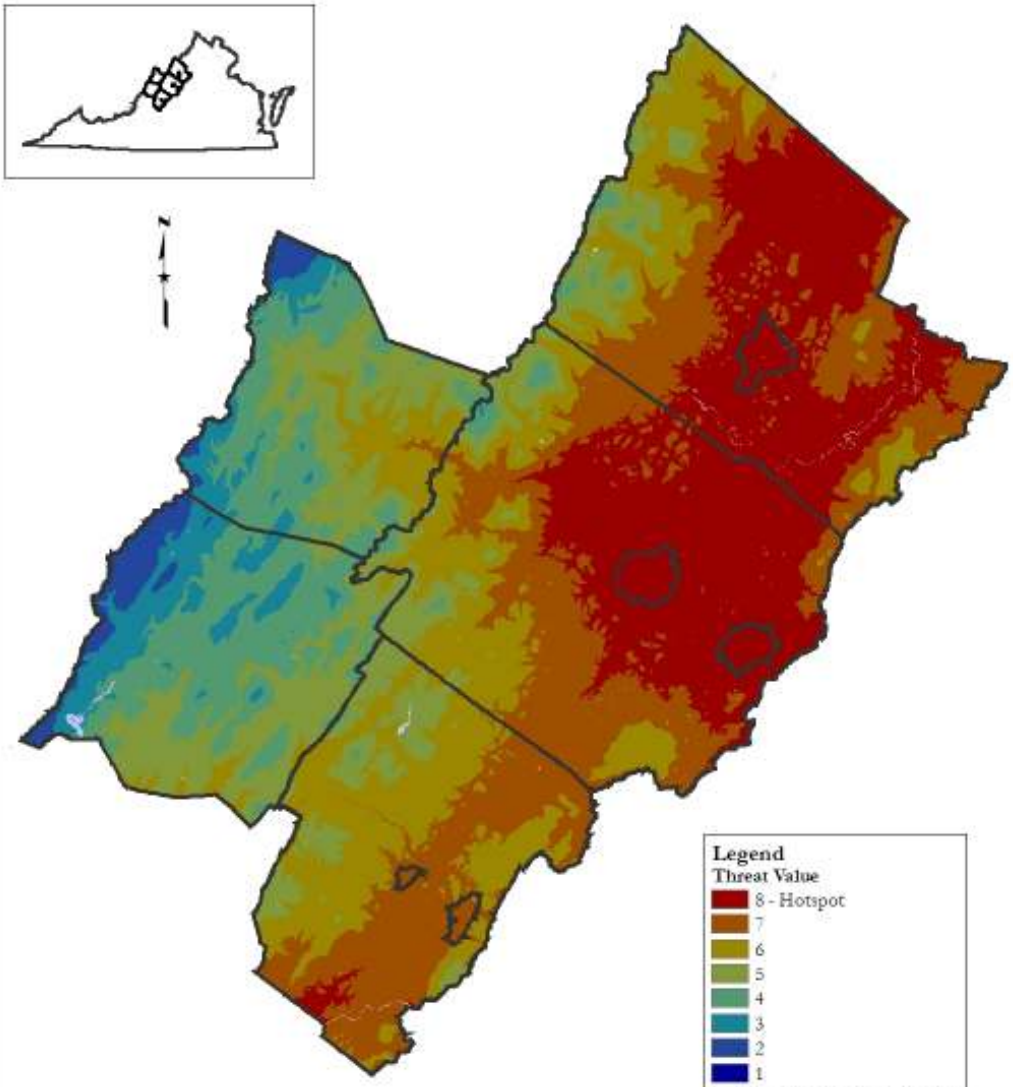
Virginia Conservation Lands Needs Assessment

Virginia Vulnerability Model

Central Shenandoah Planning District Commission

October 2008





Threat value is defined as predicted urban growth, growth at the urban fringe or growth occuring outside the urban fringe. The threat gradient reflects the predicted growth threat into the landscape on a scale of 1 (low predicted growth threat) to 8 (hotspot of growth threat).

For more information about the VCLNA and the Vulnerability Model, visit DCR's website:
http://www.dcr.virginia.gov/natural_heritage/vclna.shtml

Figure 22. PDC 6 Central Shenandoah Urban Vulnerability Model.

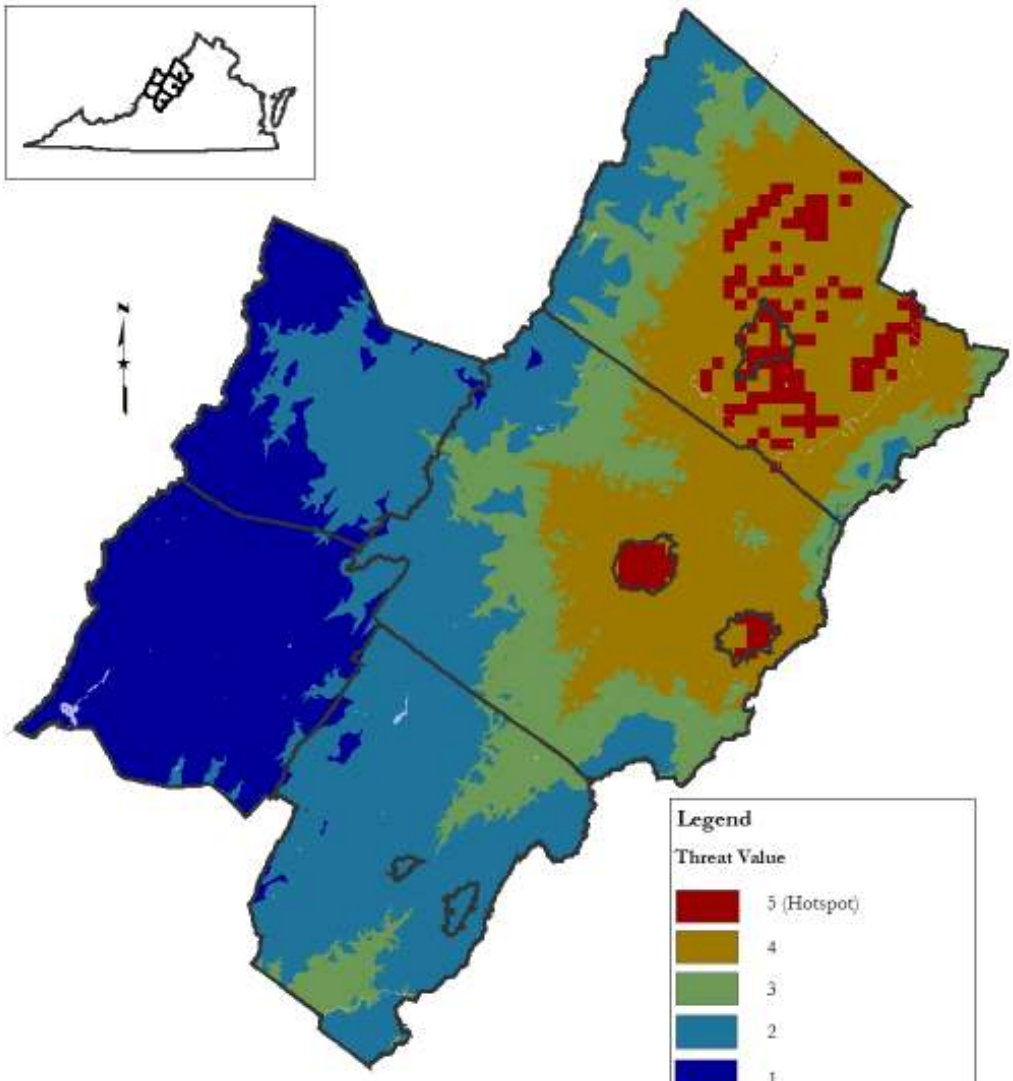
DEPARTMENT OF CONSERVATION AND RECREATION

Virginia Conservation Lands Needs Assessment

Virginia Urban Vulnerability Model

Central Shenandoah Planning District Commission

October 2006



Threat value is defined as predicted urban fringe growth. The threat gradient reflects the predicted growth threat into the landscape on a scale of 1 (low predicted growth threat) to 5 (hotspot of growth threat).

For more information about the VCLNA and the Vulnerability Model, visit DCR's website:
http://www.dcr.virginia.gov/natural_heritage/vclna.shtml

DCR VLCF VCU Virginia Coastal Zone MANAGEMENT PROGRAM

Figure 23. PDC 6 Central Shenandoah Urban Fringe Vulnerability Model.

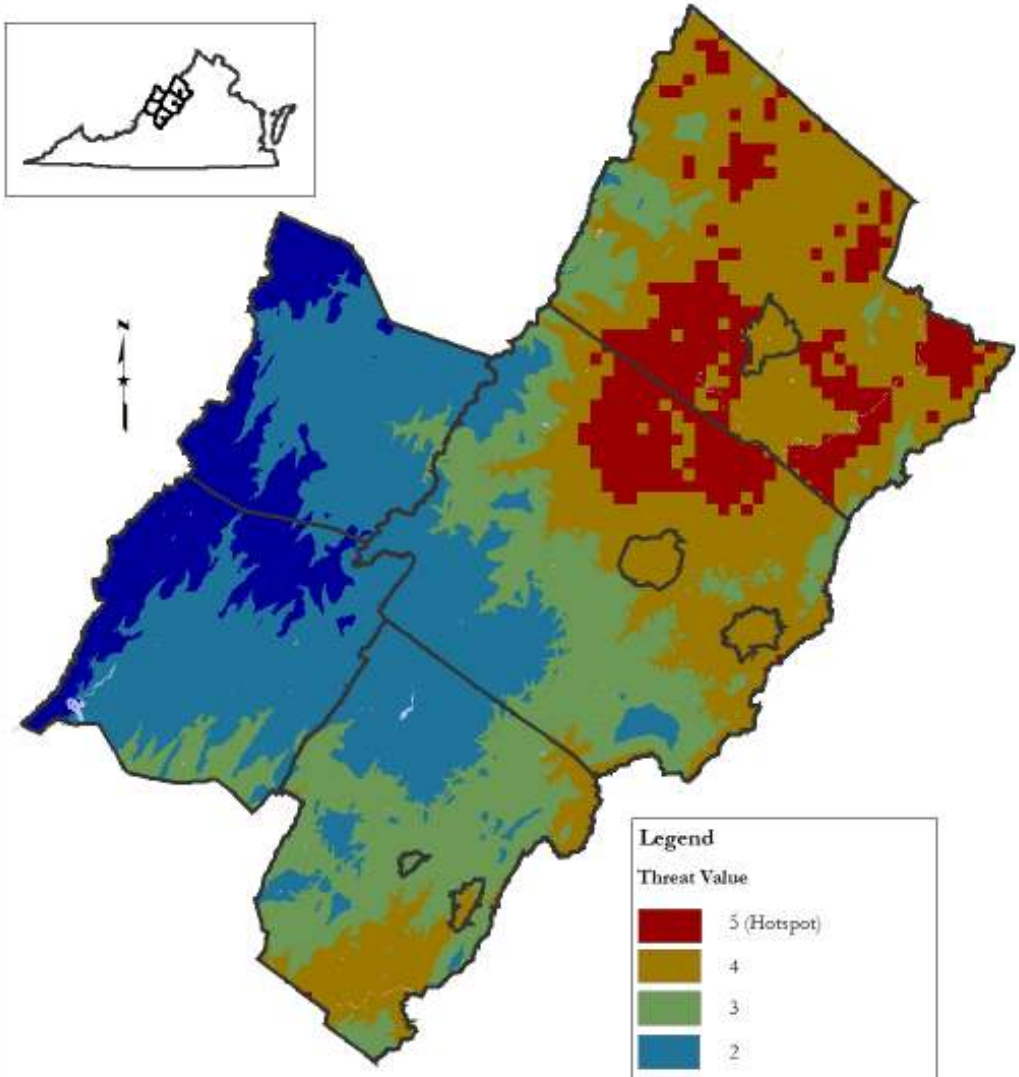
DEPARTMENT OF CONSERVATION AND RECREATION

Virginia Conservation Lands Needs Assessment

Virginia Urban Fringe Vulnerability Model

Central Shenandoah Planning District Commission

October 2008



Threat value is defined as predicted urban fringe growth. The threat gradient reflects the predicted growth threat into the landscape on a scale of 1 (low predicted growth threat) to 5 (hotspot of growth threat).

For more information about the VCLNA and the Vulnerability Model, visit DCR's website:
http://www.dcr.virginia.gov/natural_heritage/vclna.shtml

DCR Department of Conservation & Recreation
VLCF Virginia Land Conservation Foundation
VCU
Virginia Coastal Zone MANAGEMENT PROGRAM
Chesapeake Bay Program

Figure 24. PDC 6 Central Shenandoah Outside the Urban Fringe Vulnerability Model.

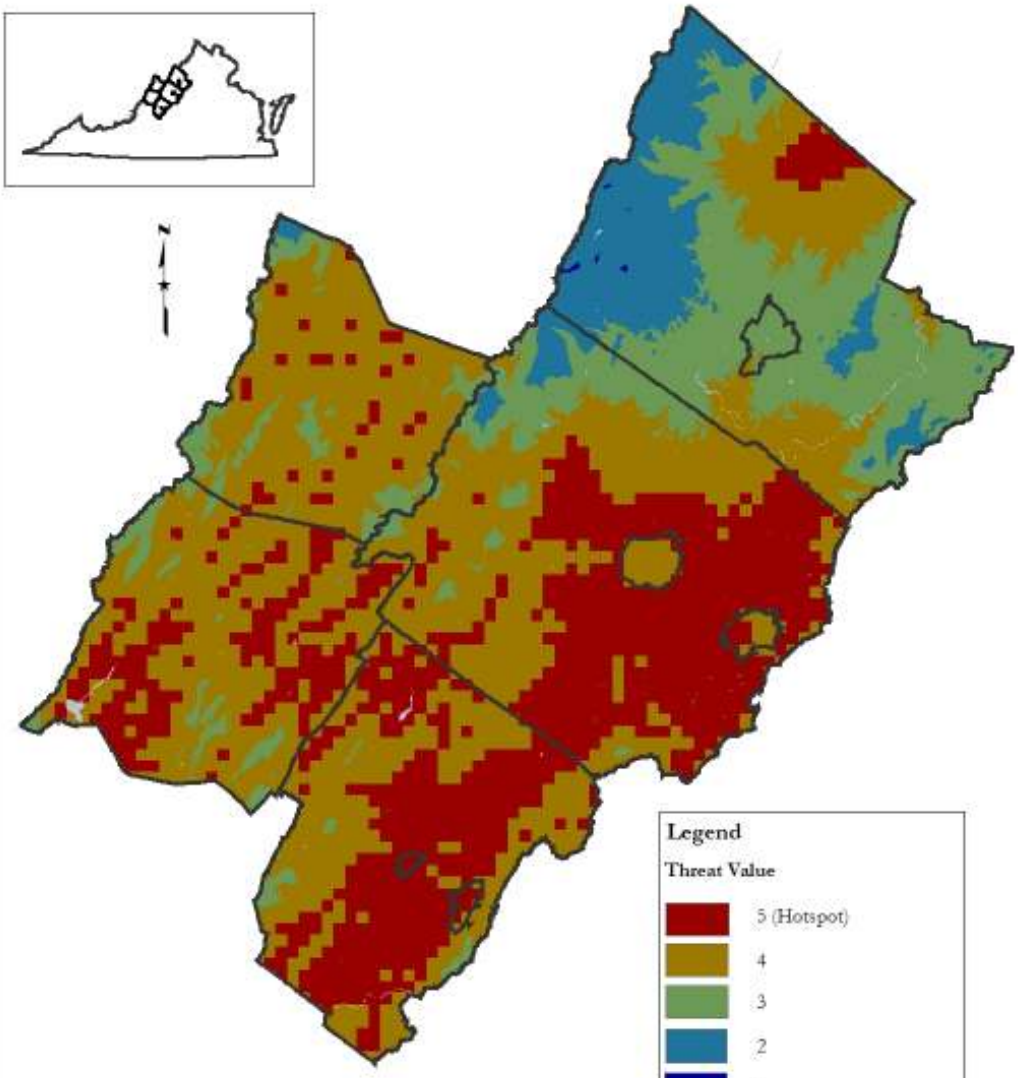
DEPARTMENT OF CONSERVATION AND RECREATION

Virginia Conservation Lands Needs Assessment

Virginia Outside the Urban Fringe Vulnerability Model

Central Shenandoah Planning District Commission

October 2008



Legend

Threat Value

- 5 (Hotspot)
- 4
- 3
- 2
- 1
- County and City Boundary
- Waterbody

0 3 6 12 18 24 Miles

Threat value is defined as predicted growth outside the urban fringe. The threat gradient reflects the predicted growth threat into the landscape on a scale of 1 (low predicted growth threat) to 5 (hotspot of growth threat).

For more information about the VCLNA and the Vulnerability Model, visit DCR's website:
http://www.dcr.virginia.gov/natural_heritage/vclna.shtml

DCR Department of Conservation & Recreation

VLCF Virginia Land Conservation Foundation

VCU

Virginia Coastal Zone MANAGEMENT PROGRAM

Chesapeake Bay Program

Figure 25. PDC 7 Northern Shenandoah Valley Regional Commission Vulnerability Model

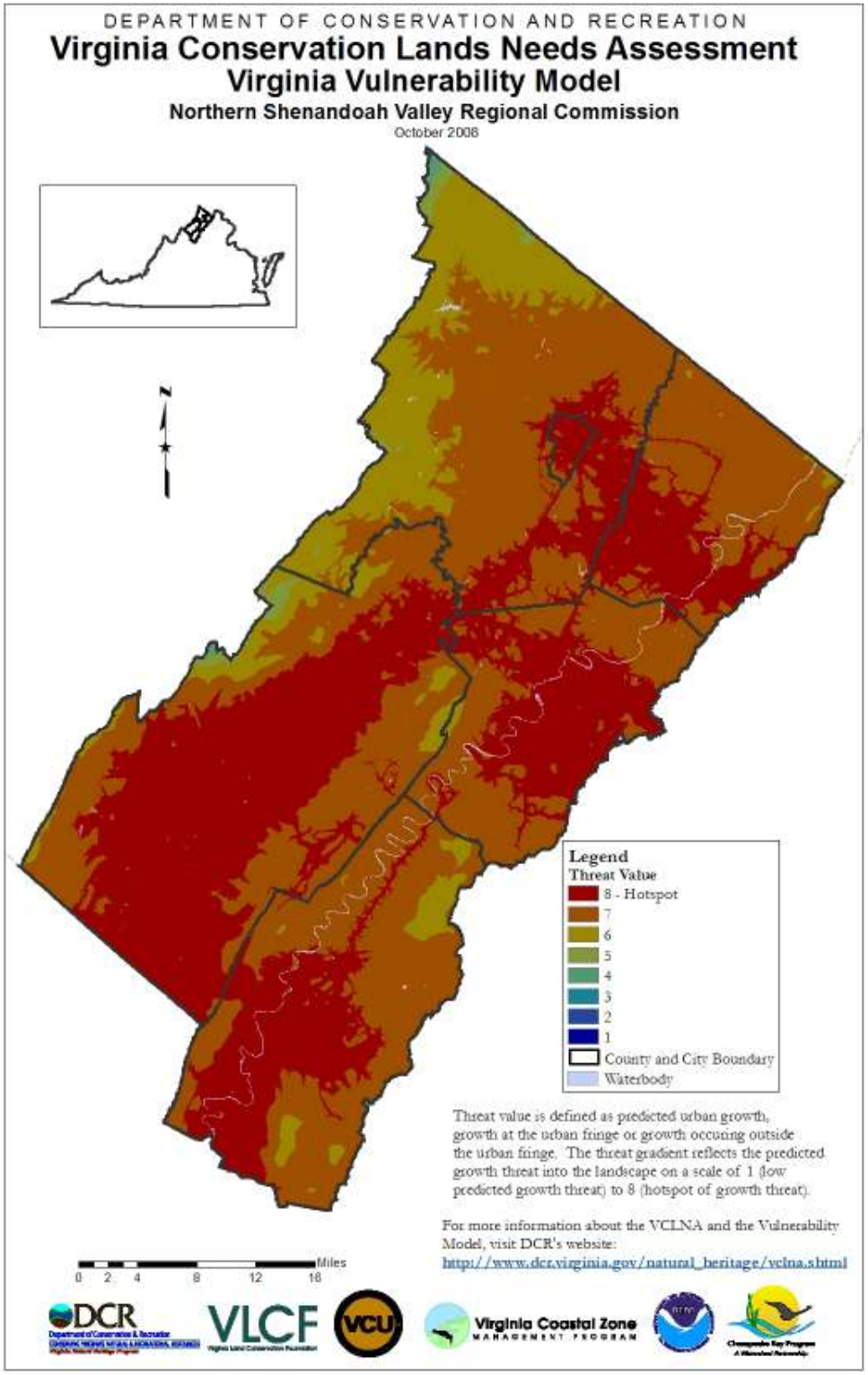


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Figure 26. PDC 7 Northern Shenandoah Valley Regional Commission Urban Vulnerability Model.

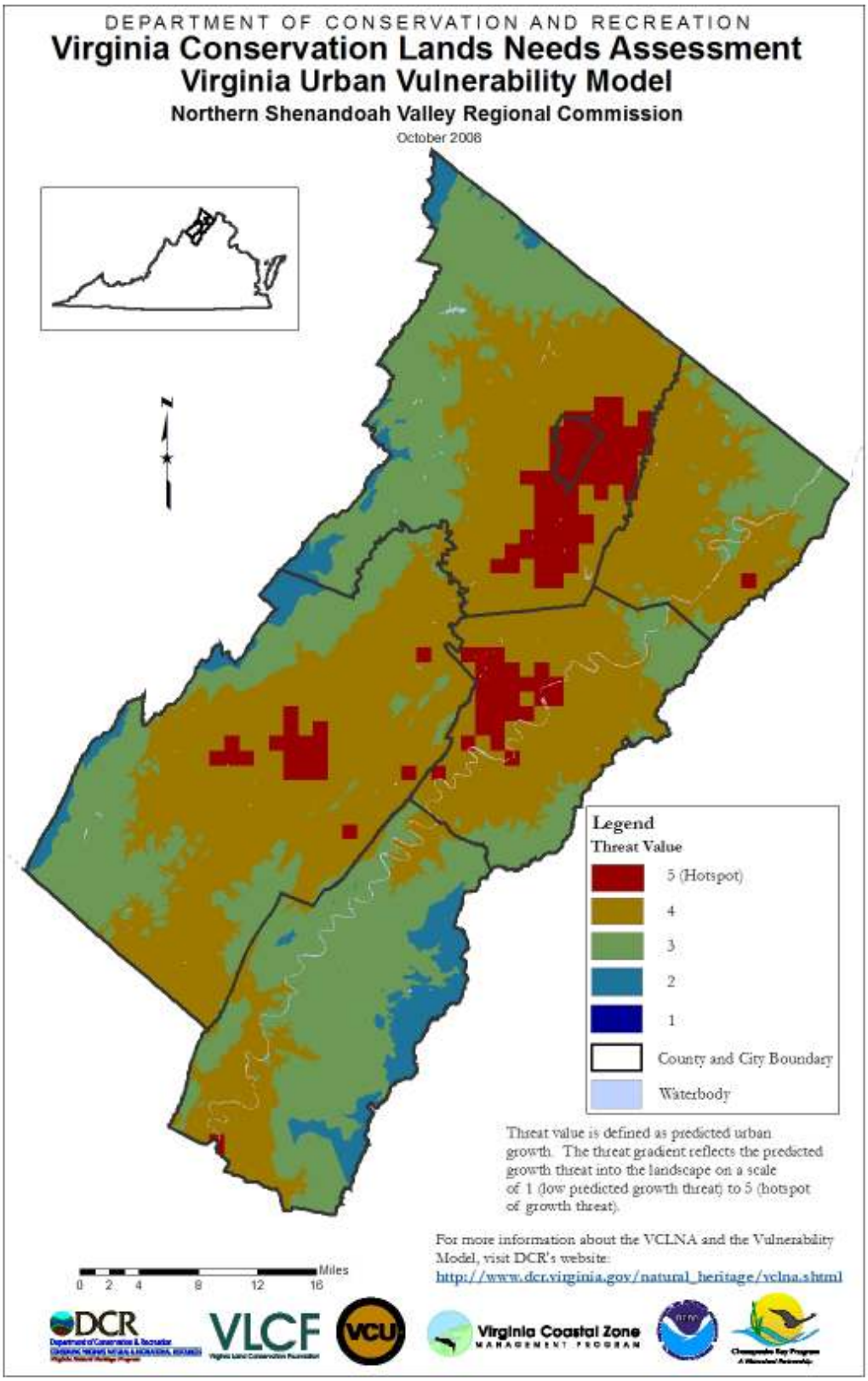

Figure 27. PDC 7 Northern Shenandoah Valley Regional Commission Urban Fringe Vulnerability Model.

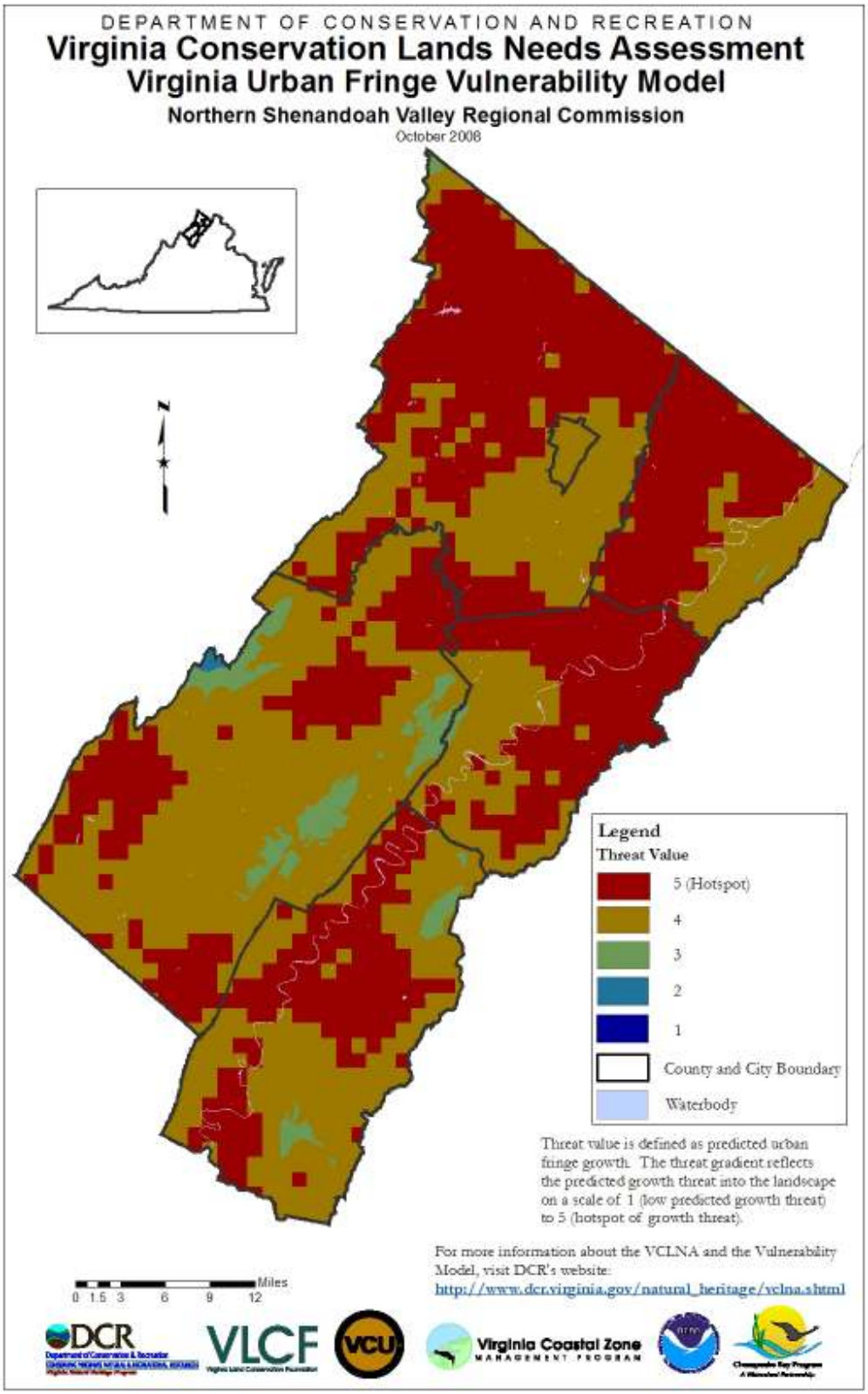

Figure 28. PDC 7 Northern Shenandoah Valley Regional Commission Outside the Urban Fringe Vulnerability Model.

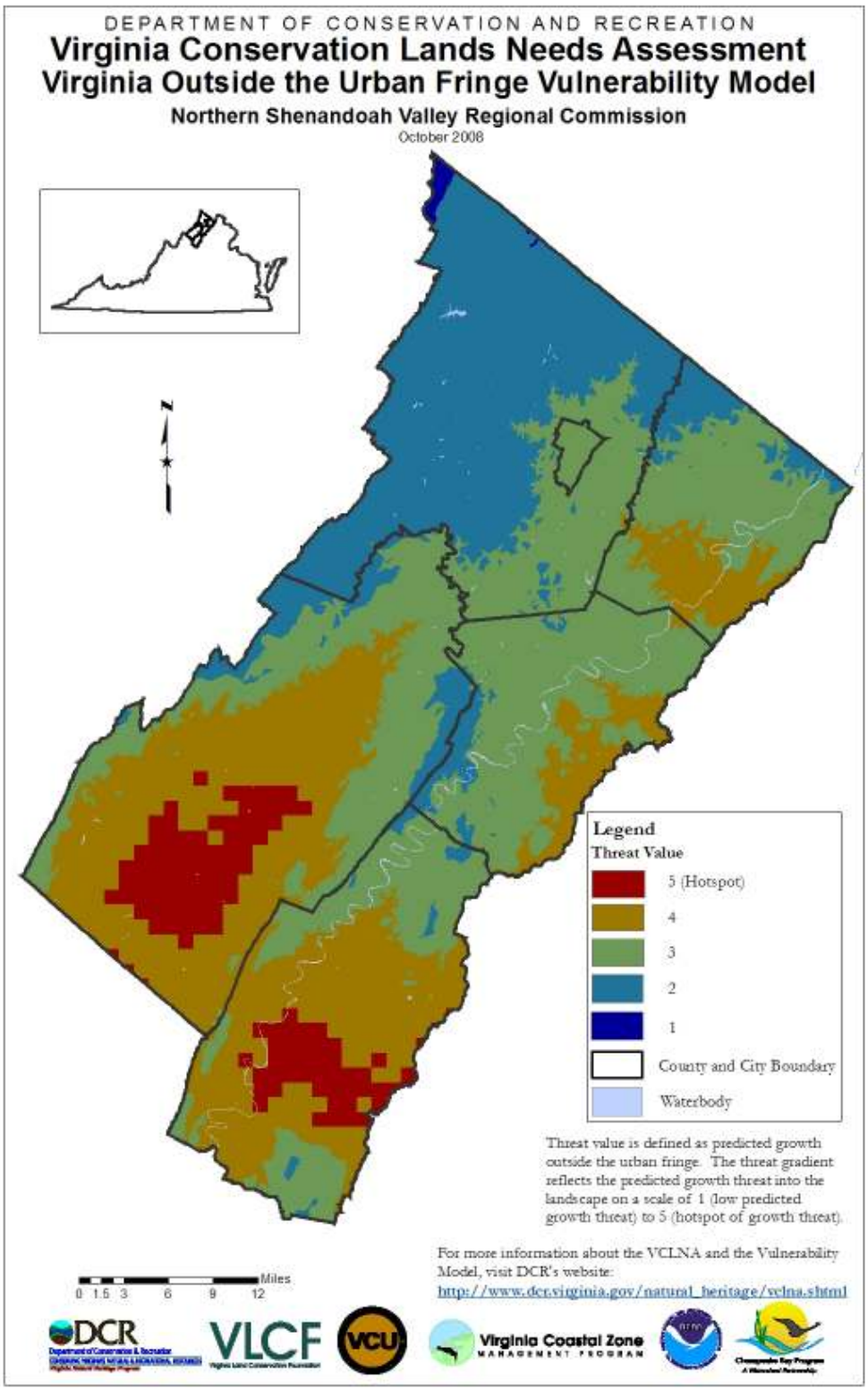

Figure 29. PDC 8 Northern Virginia Regional Commission Vulnerability Model.

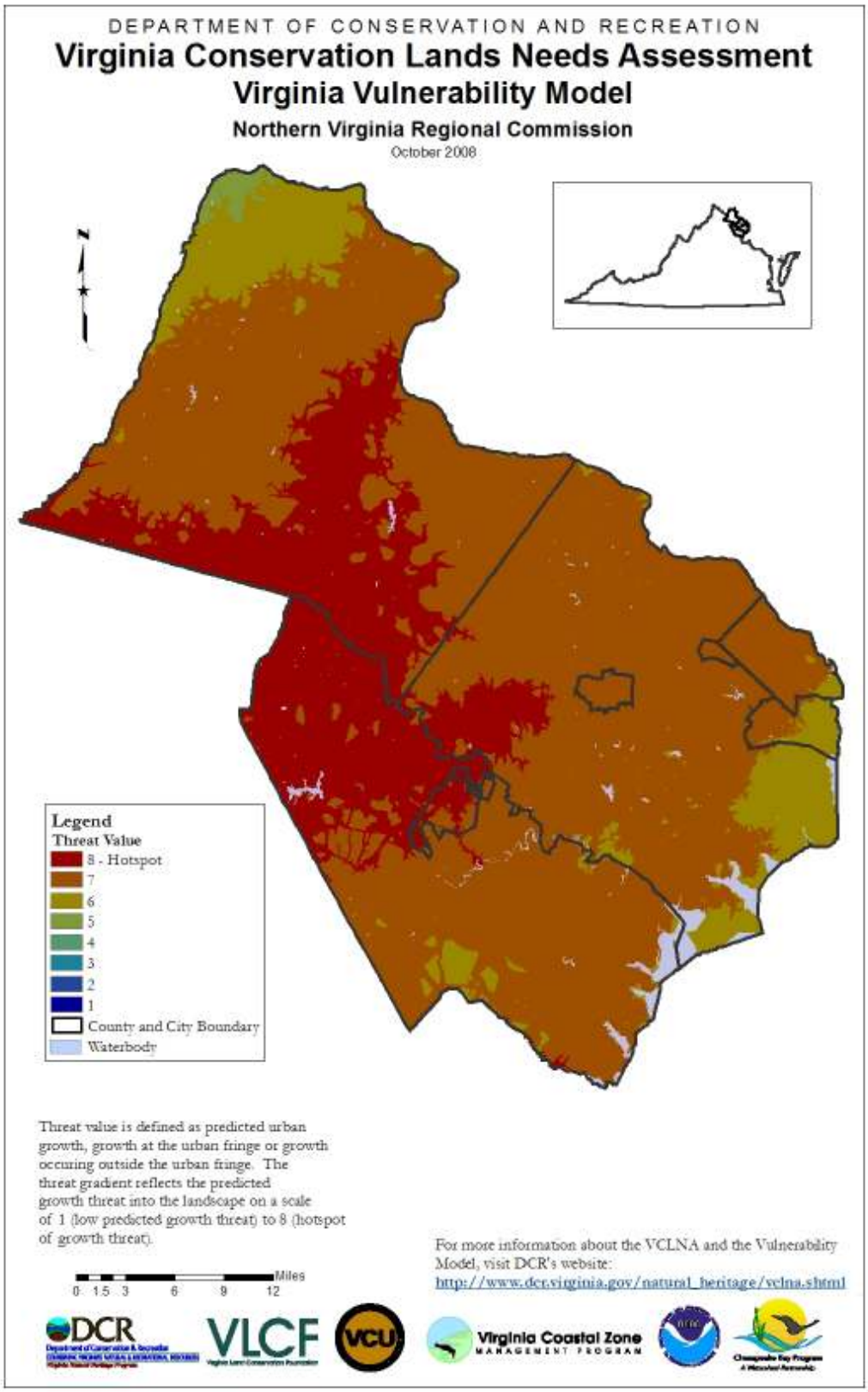

Figure 30. PDC 8 Northern Virginia Regional Commission Urban Vulnerability Model.

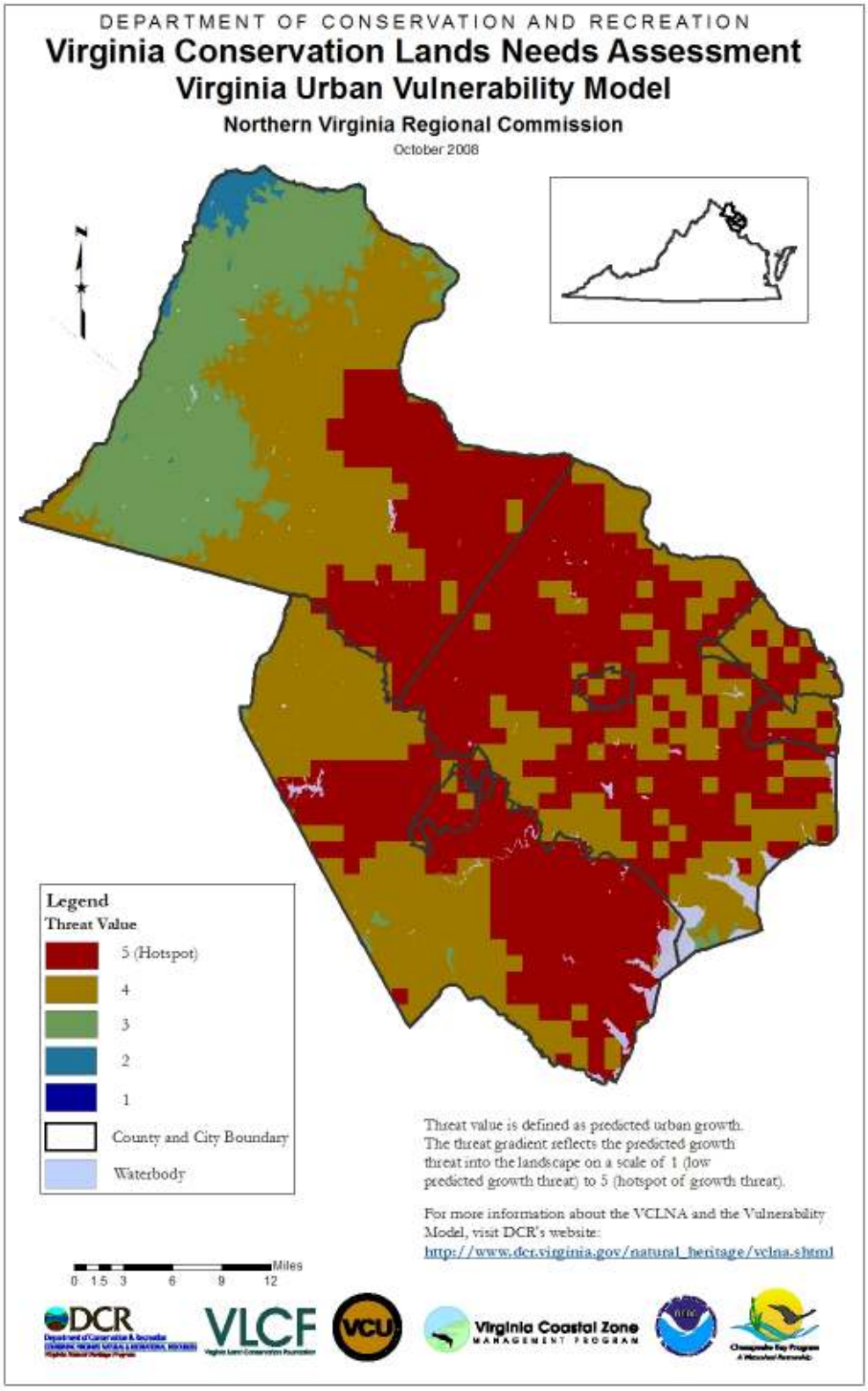

Figure 31. PDC 8 Northern Virginia Regional Commission Urban Fringe Vulnerability Model.

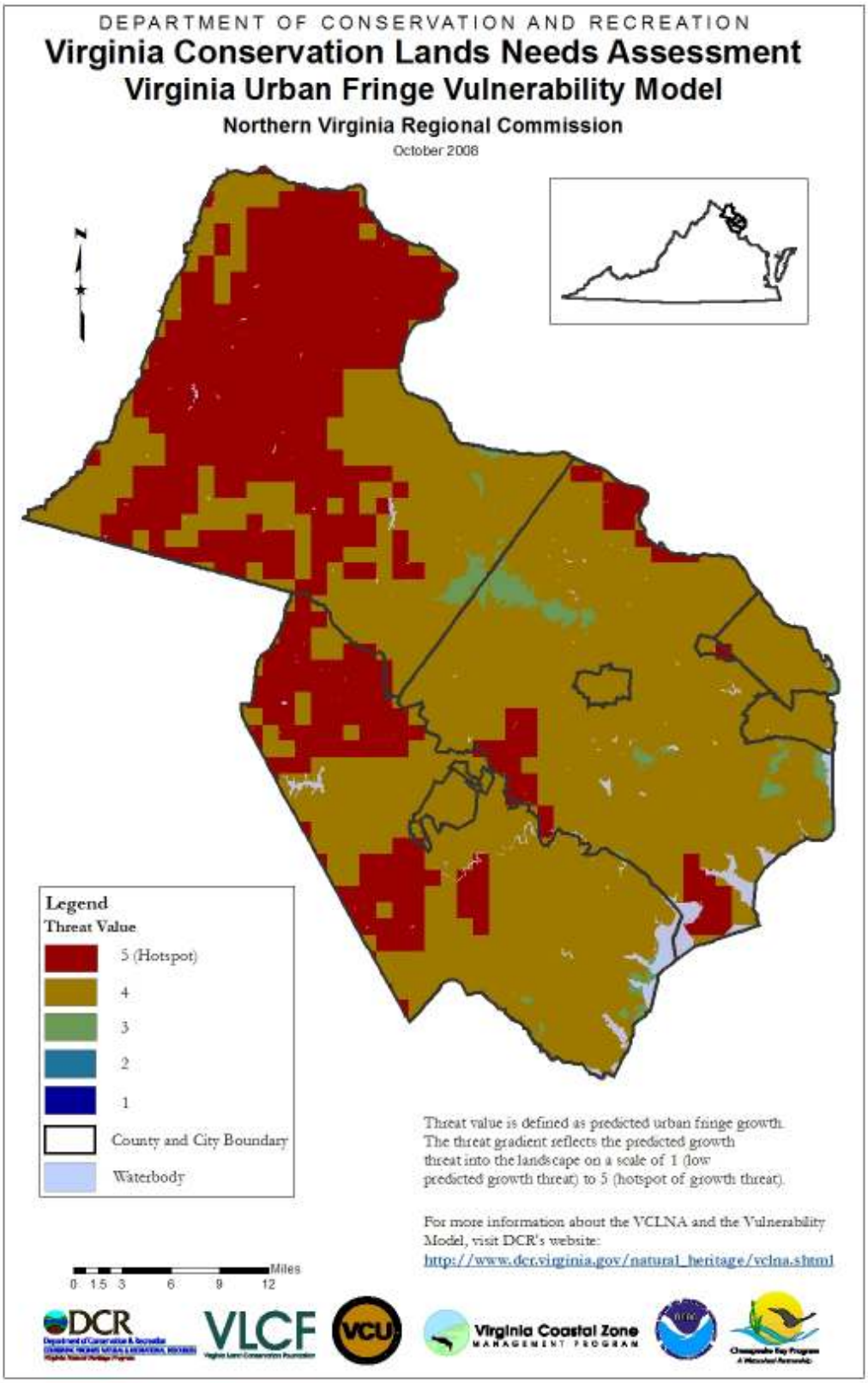

Figure 32. PDC 8 Northern Virginia Regional Commission Outside the Urban Fringe Vulnerability Model.

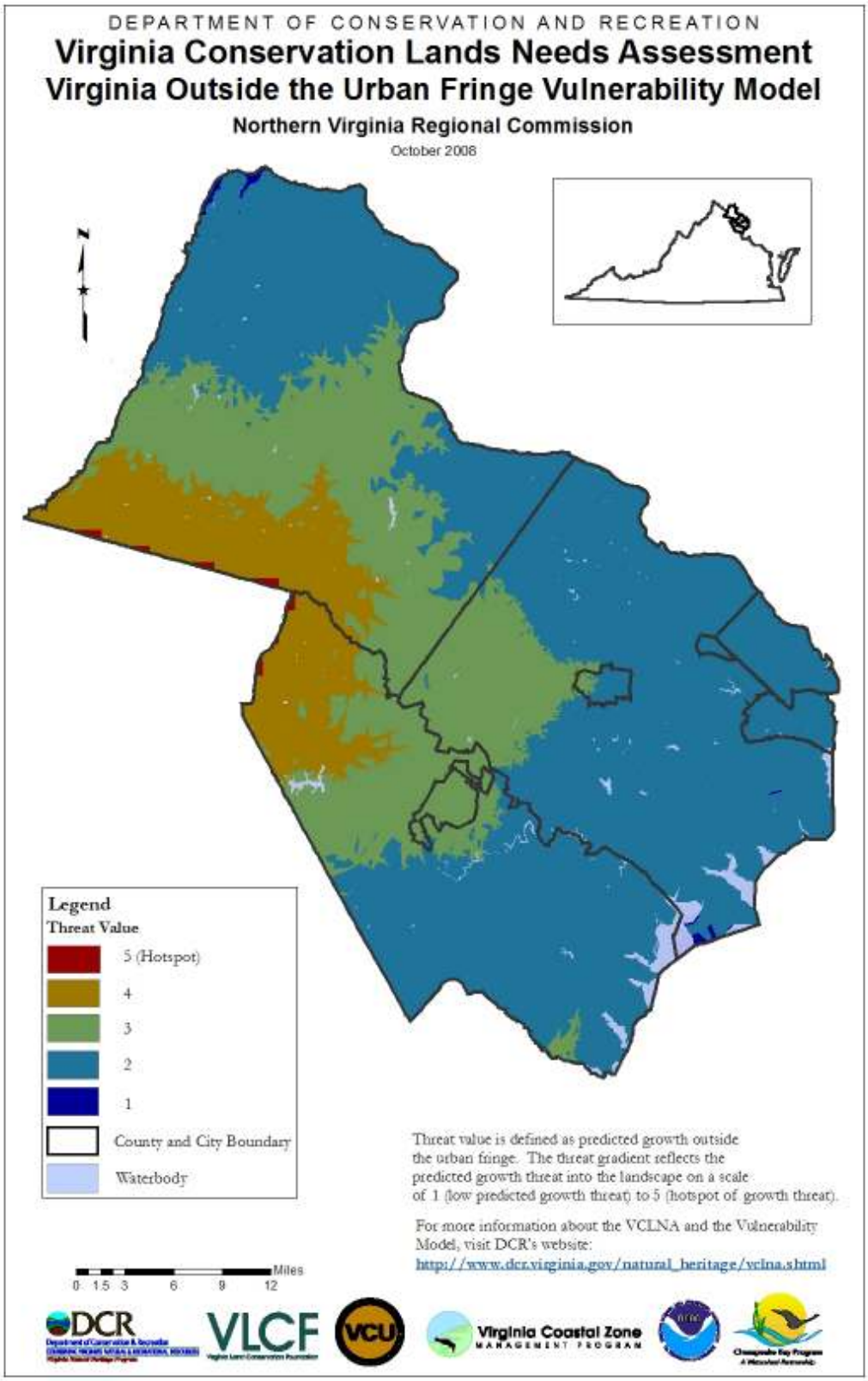

Figure 33. PDC 9 Rappahannock-Rapidan Regional Commission Vulnerability Model.

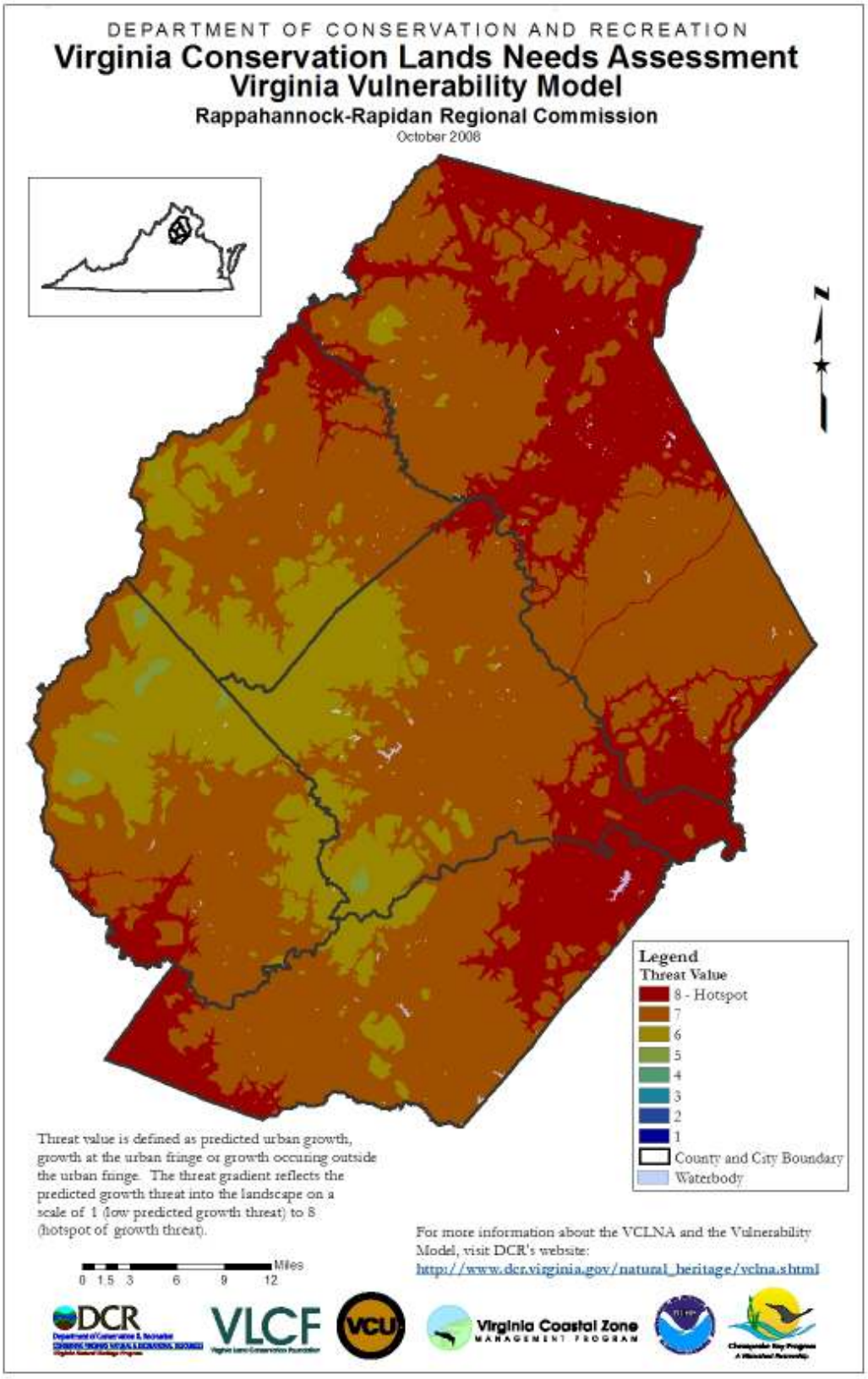

Figure 34. PDC 9 Rappahannock-Rapidan Regional Commission Urban Vulnerability Model.

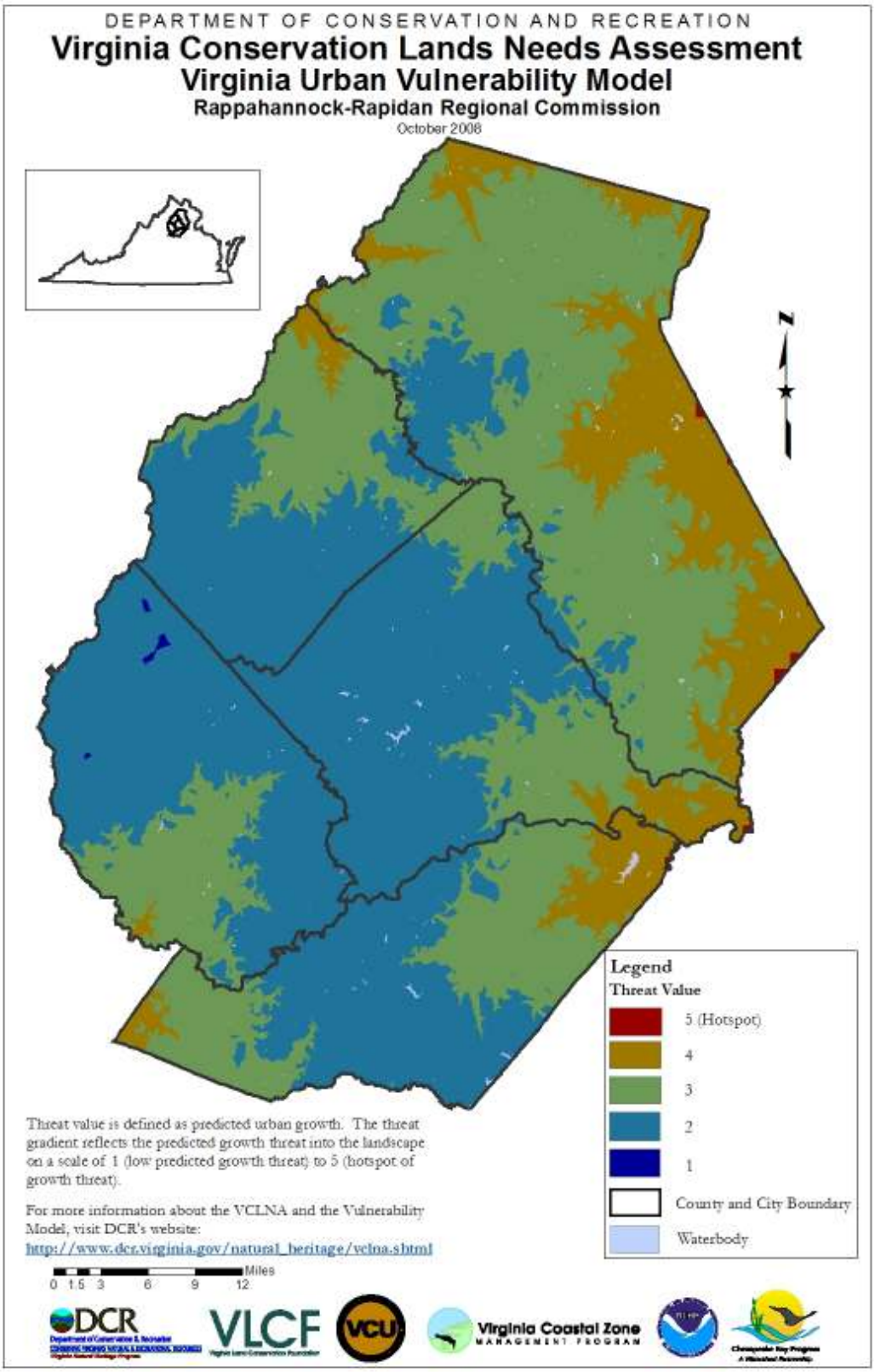

Figure 35. PDC 9 Rappahannock-Rapidan Regional Commission Urban Fringe Vulnerability Model.

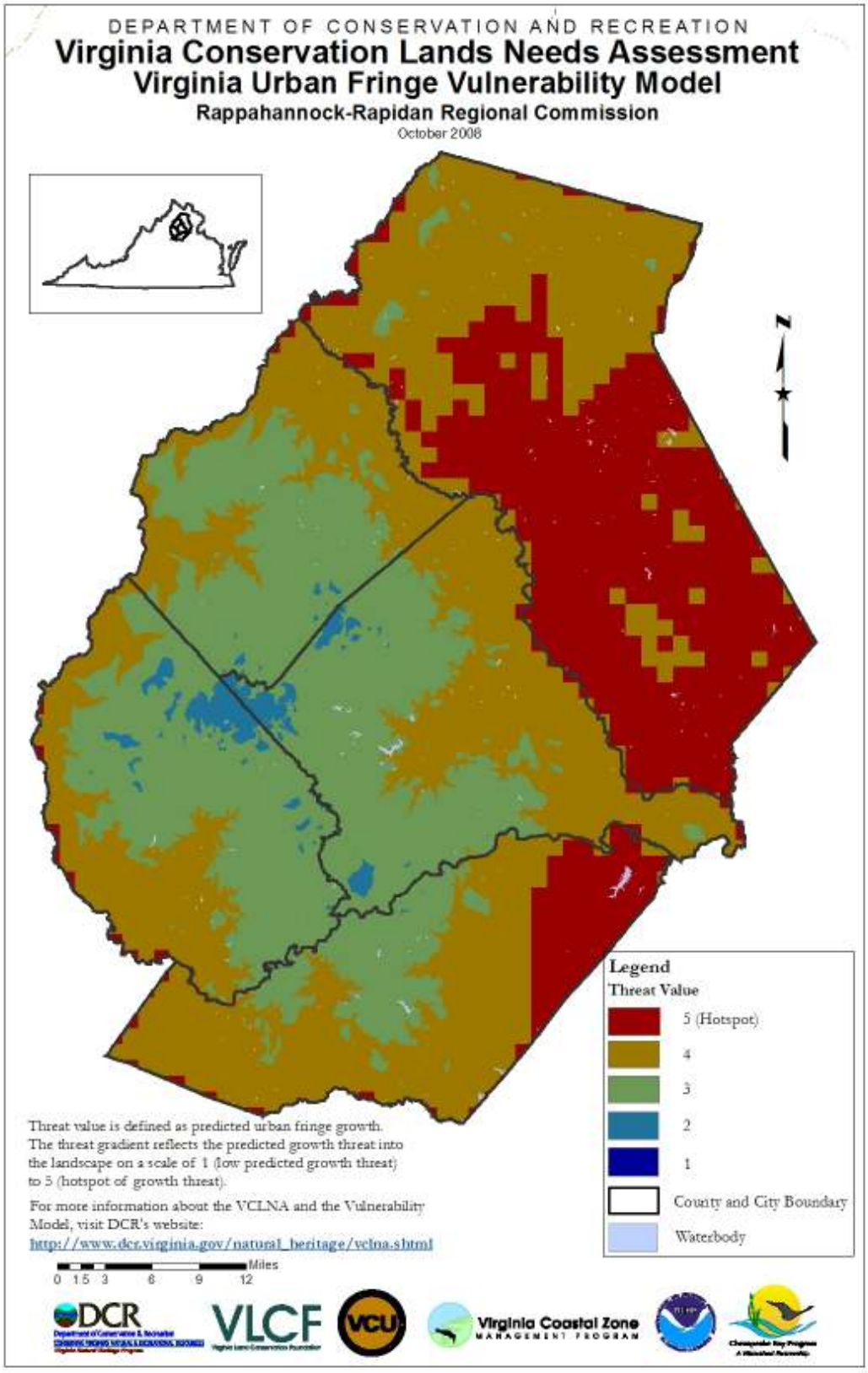

Figure 36. PDC 9 Rappahannock-Rapidan Regional Commission Outside the Urban Fringe Vulnerability Model.

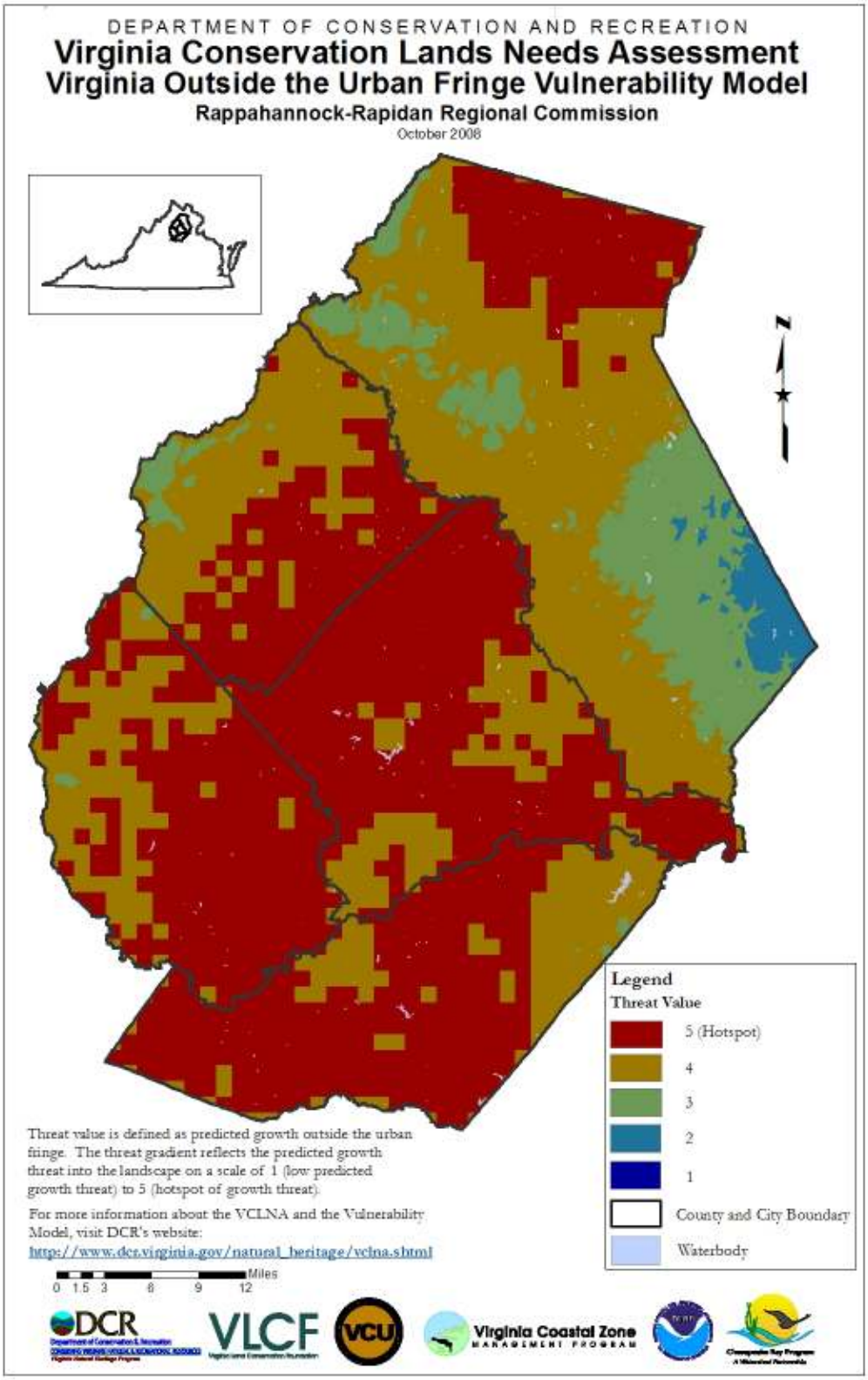

Figure 37. PDC 10 Thomas Jefferson Planning District Commission Vulnerability Model.

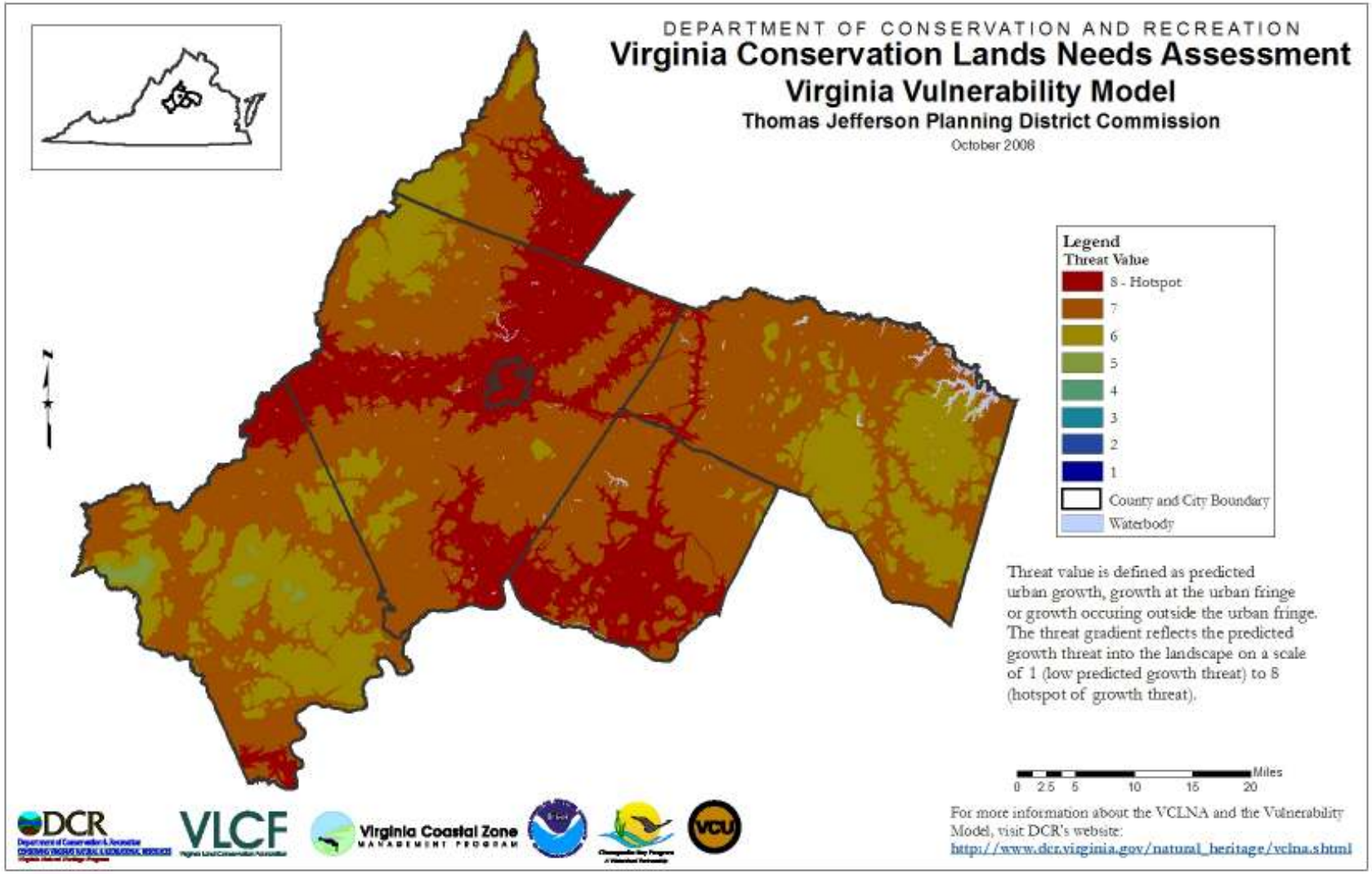

Figure 38. PDC 10 Thomas Jefferson Planning District Commission Urban Vulnerability Model.

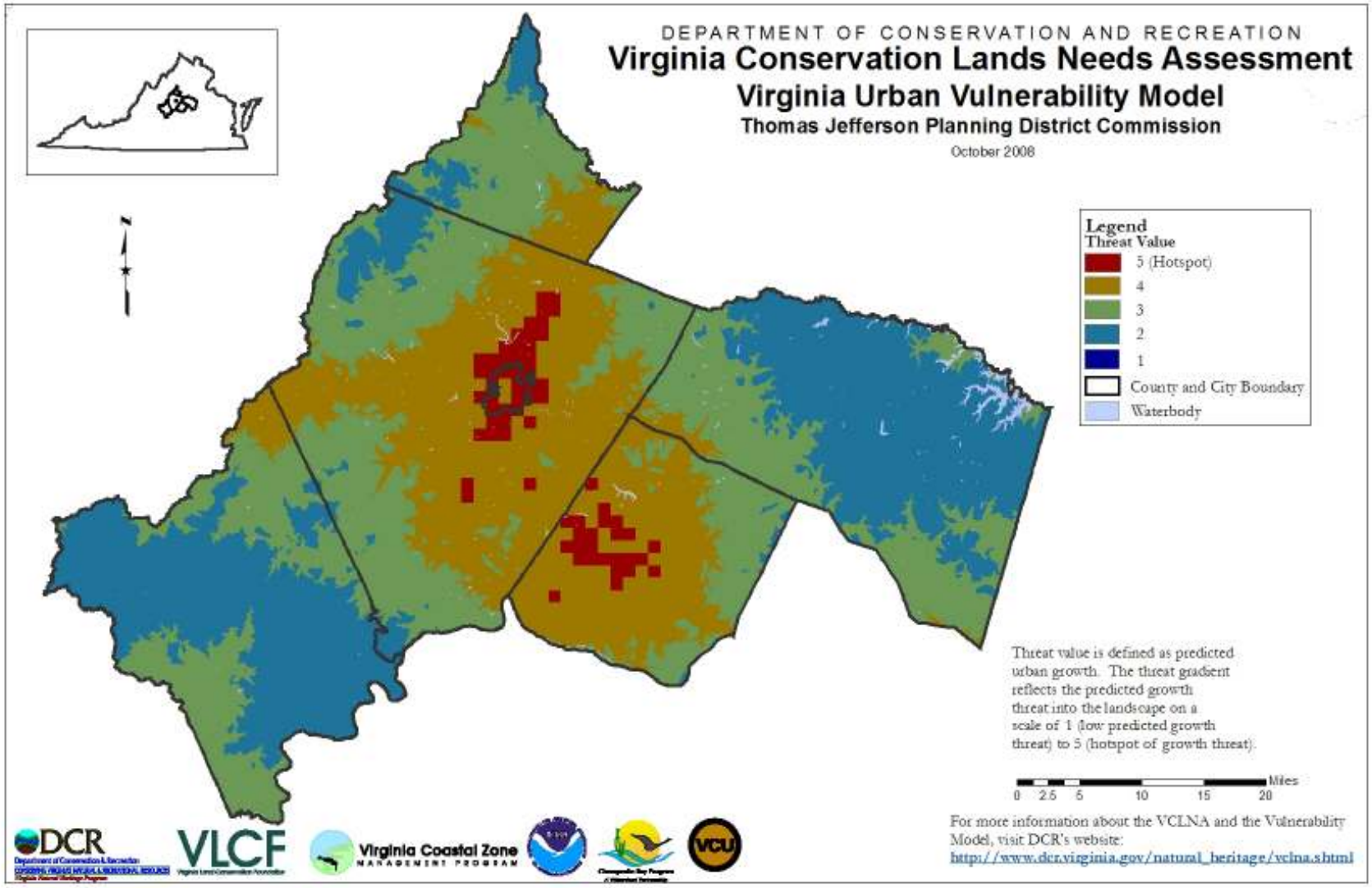

Figure 39. PDC 10 Thomas Jefferson Planning District Commission Urban Fringe Vulnerability Model.

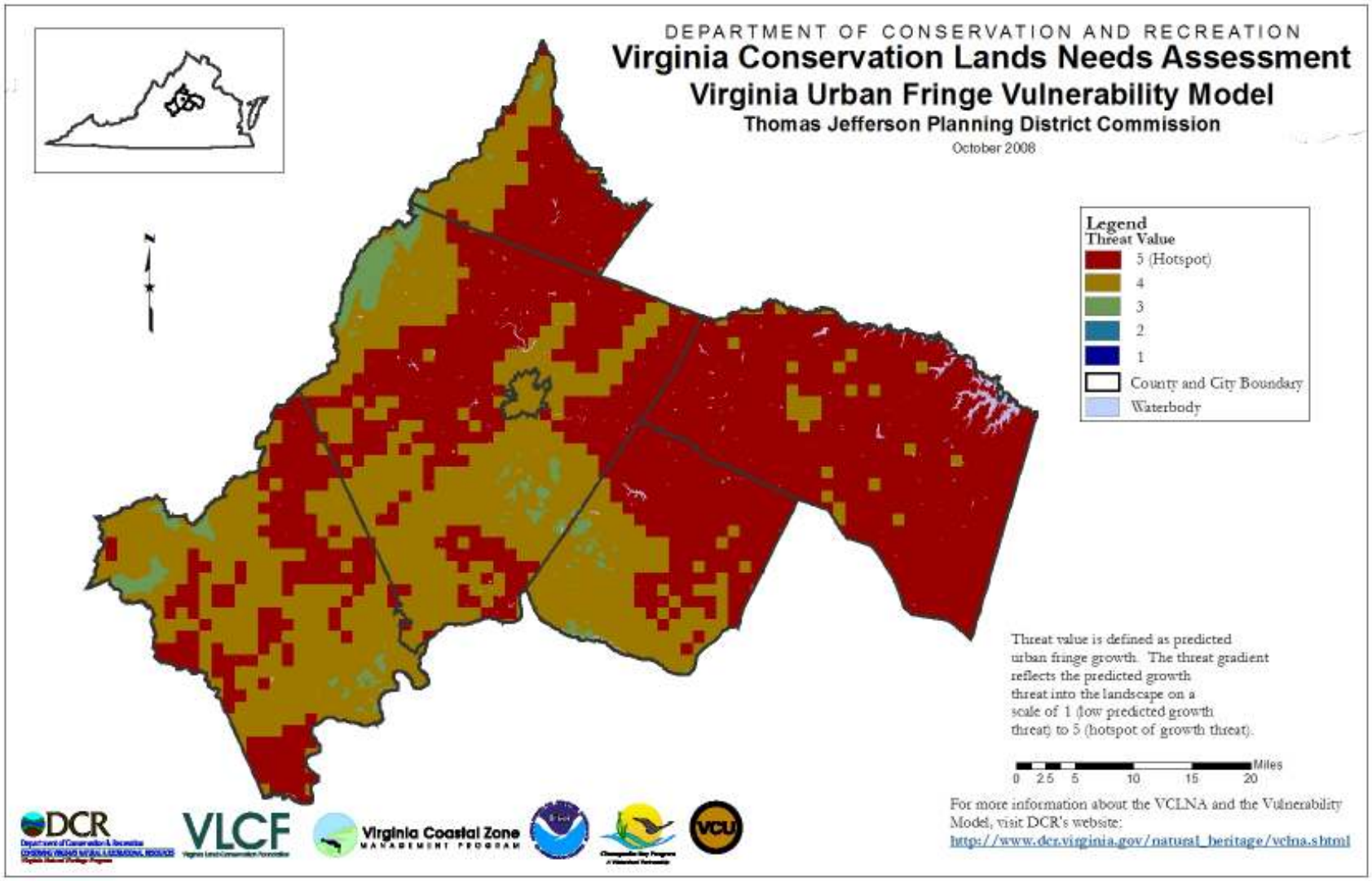

Figure 40. PDC 10 Thomas Jefferson Planning District Commission Outside the Urban Fringe Vulnerability Model.

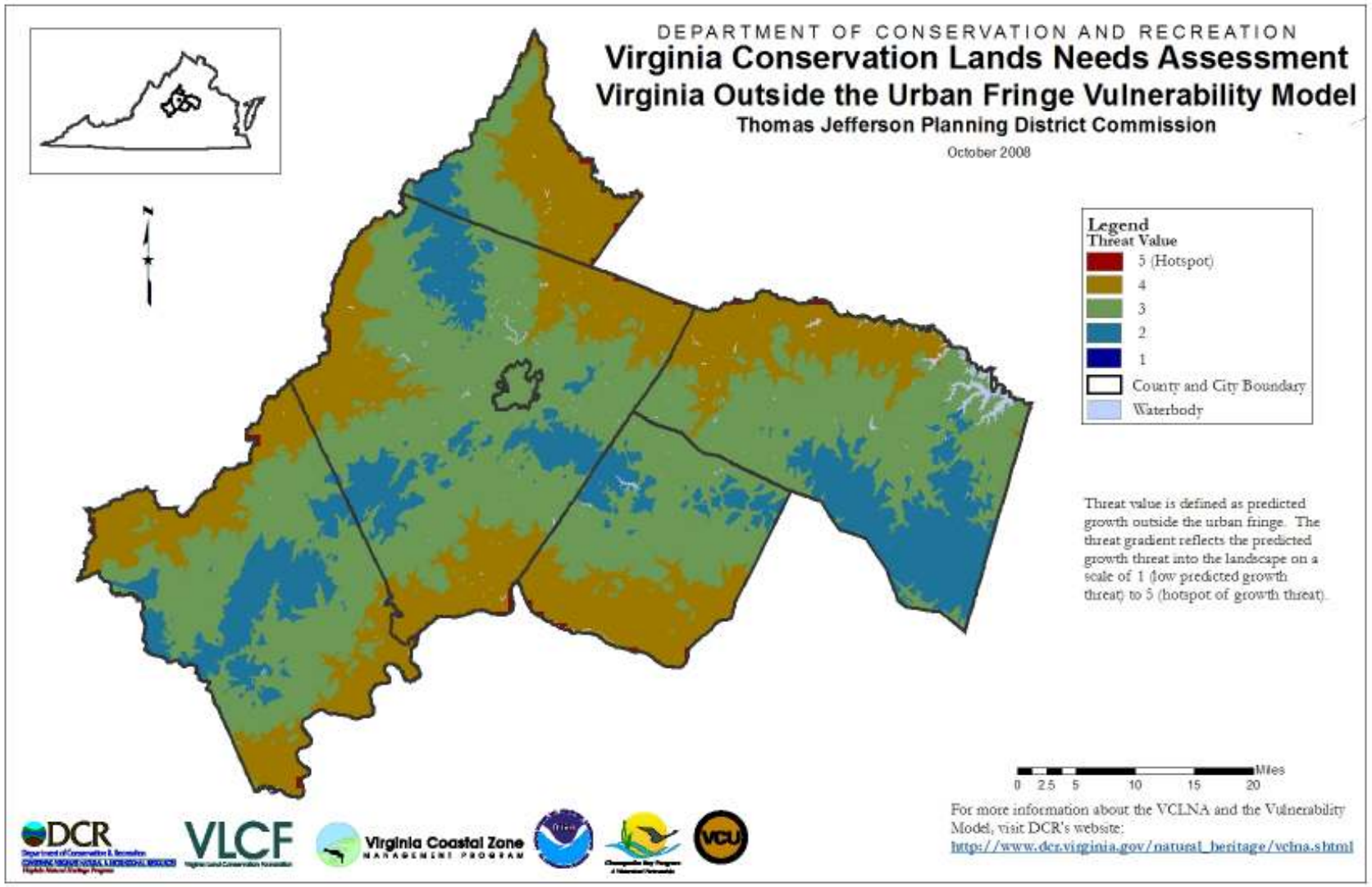

Figure 41. PDC 11 Region 2000 Local Government Council Vulnerability Model.

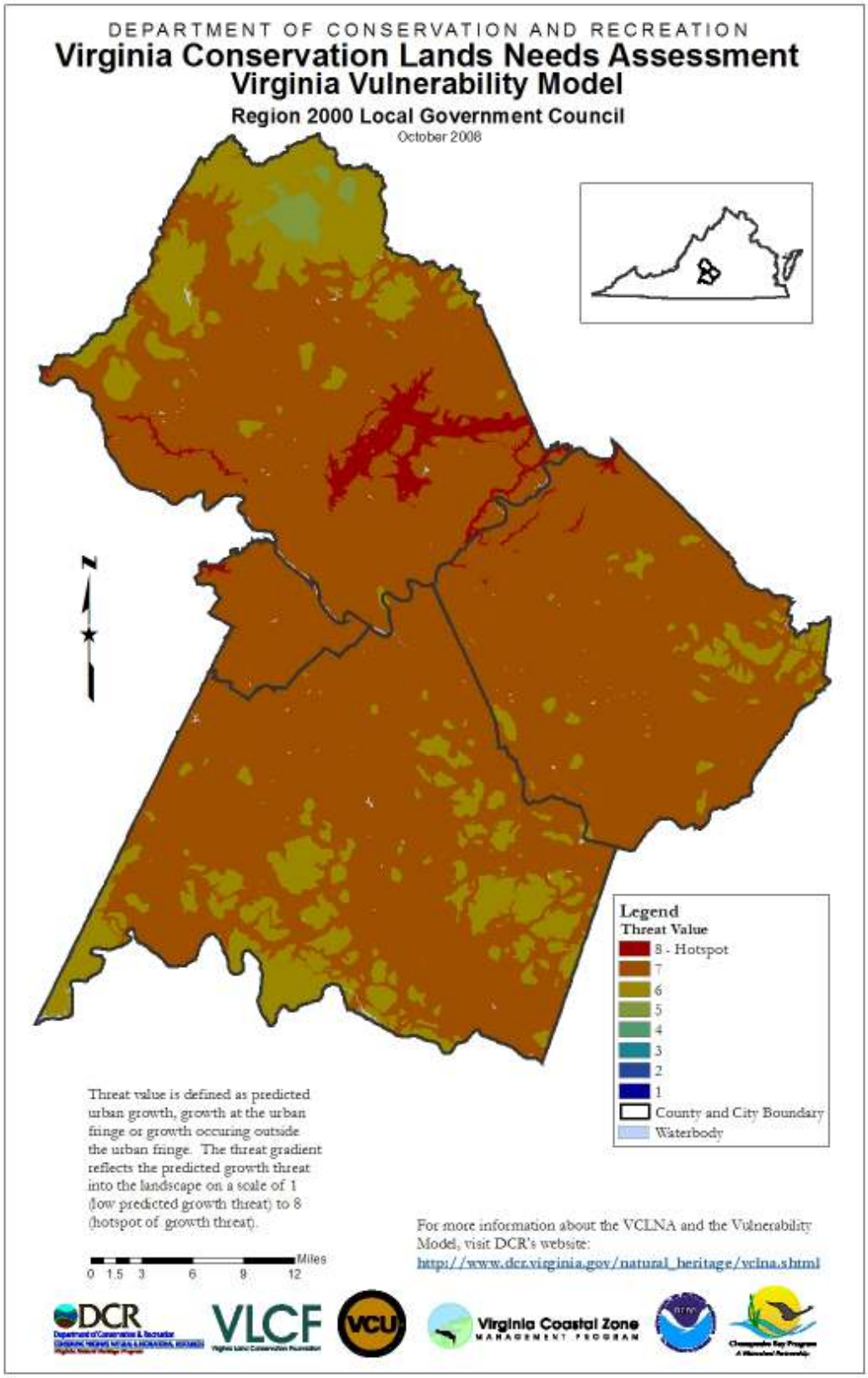

Figure 42. PDC 11 Region 2000 Local Government Council Urban Vulnerability Model.

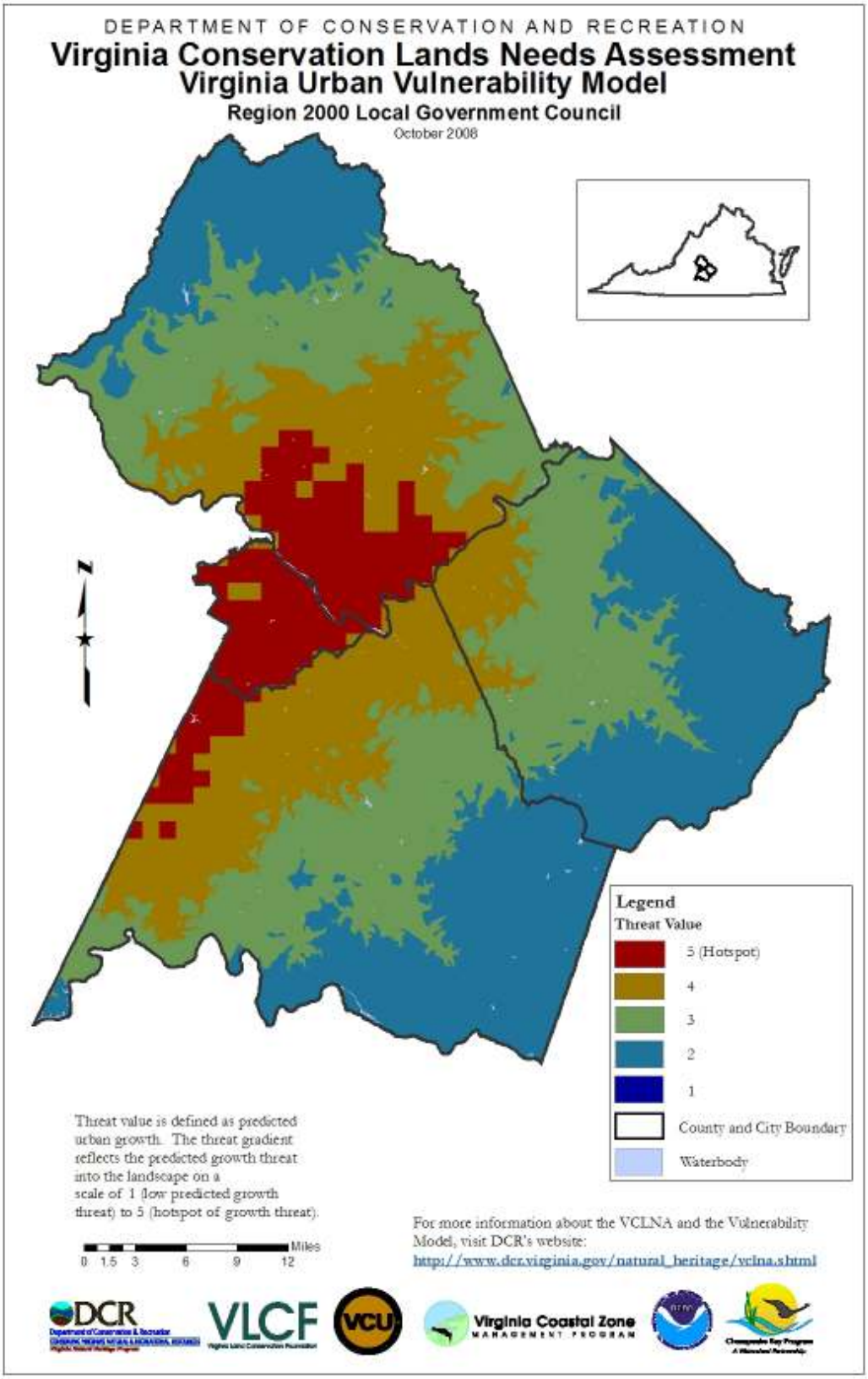

Figure 43. PDC 11 Region 2000 Local Government Council Urban Fringe Vulnerability Model.

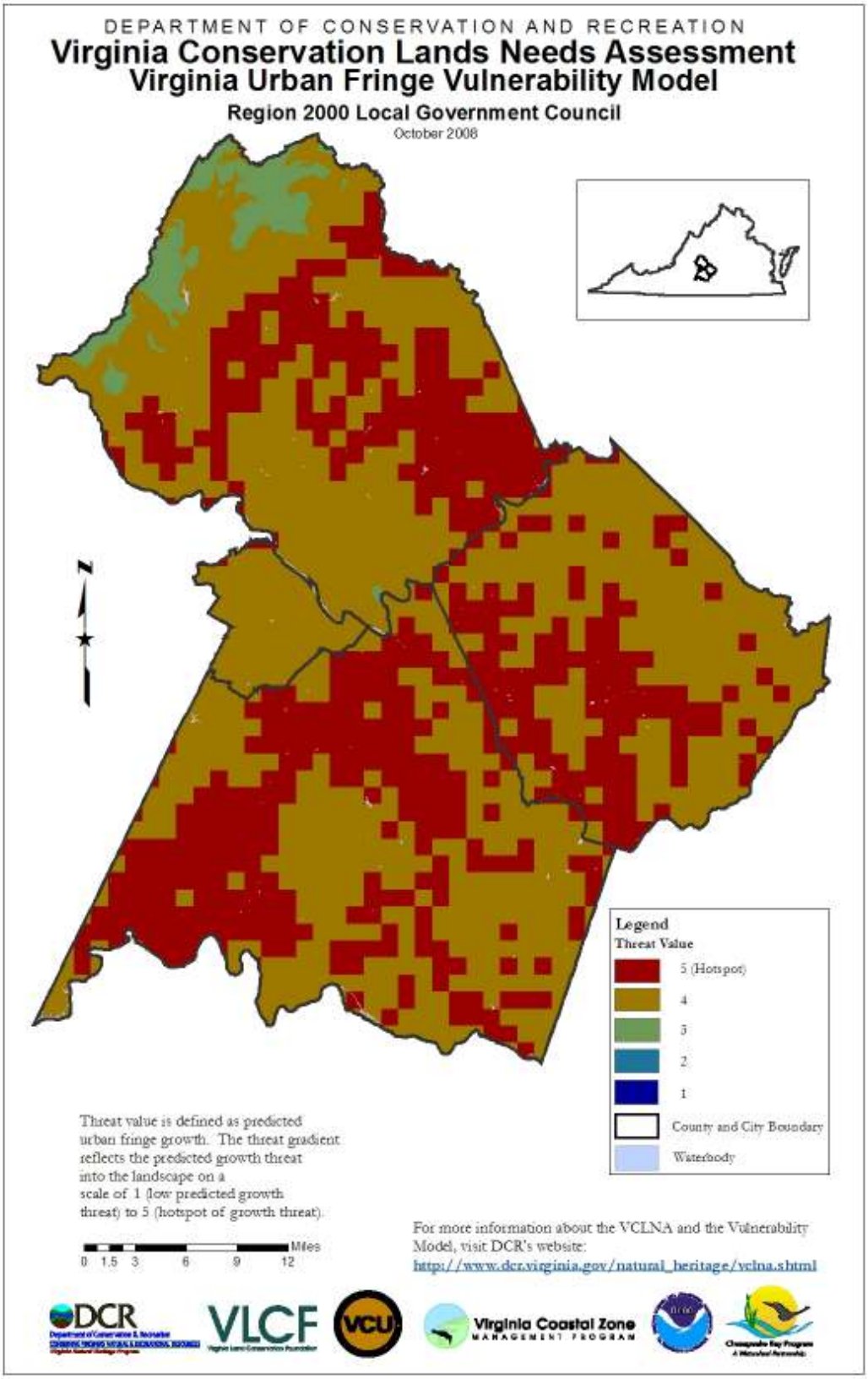

Figure 44. PDC 11 Region 2000 Local Government Council Outside the Urban Fringe Vulnerability Model.

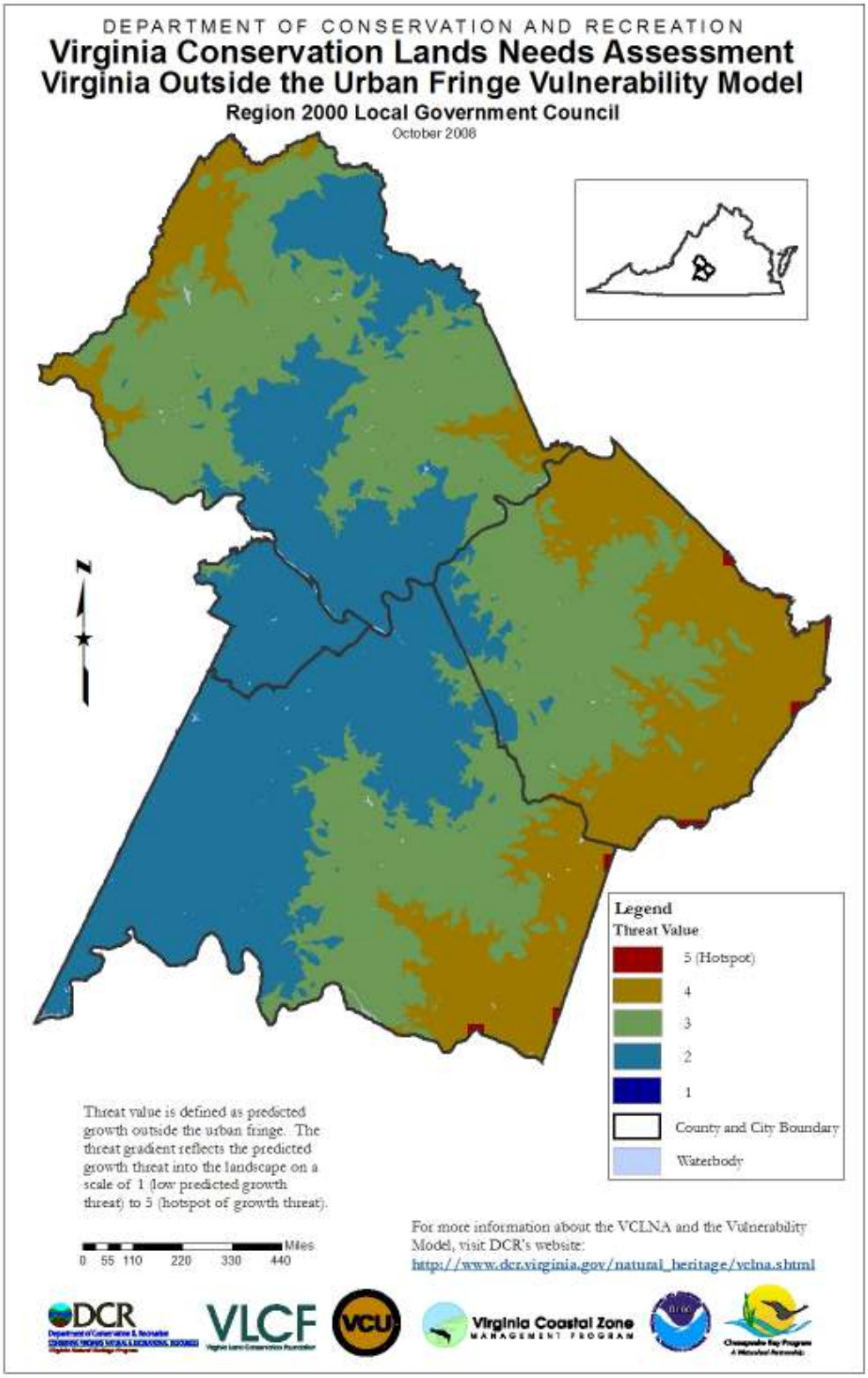

Figure 45. PDC 12 West Piedmont Planning District Commission Vulnerability Model.

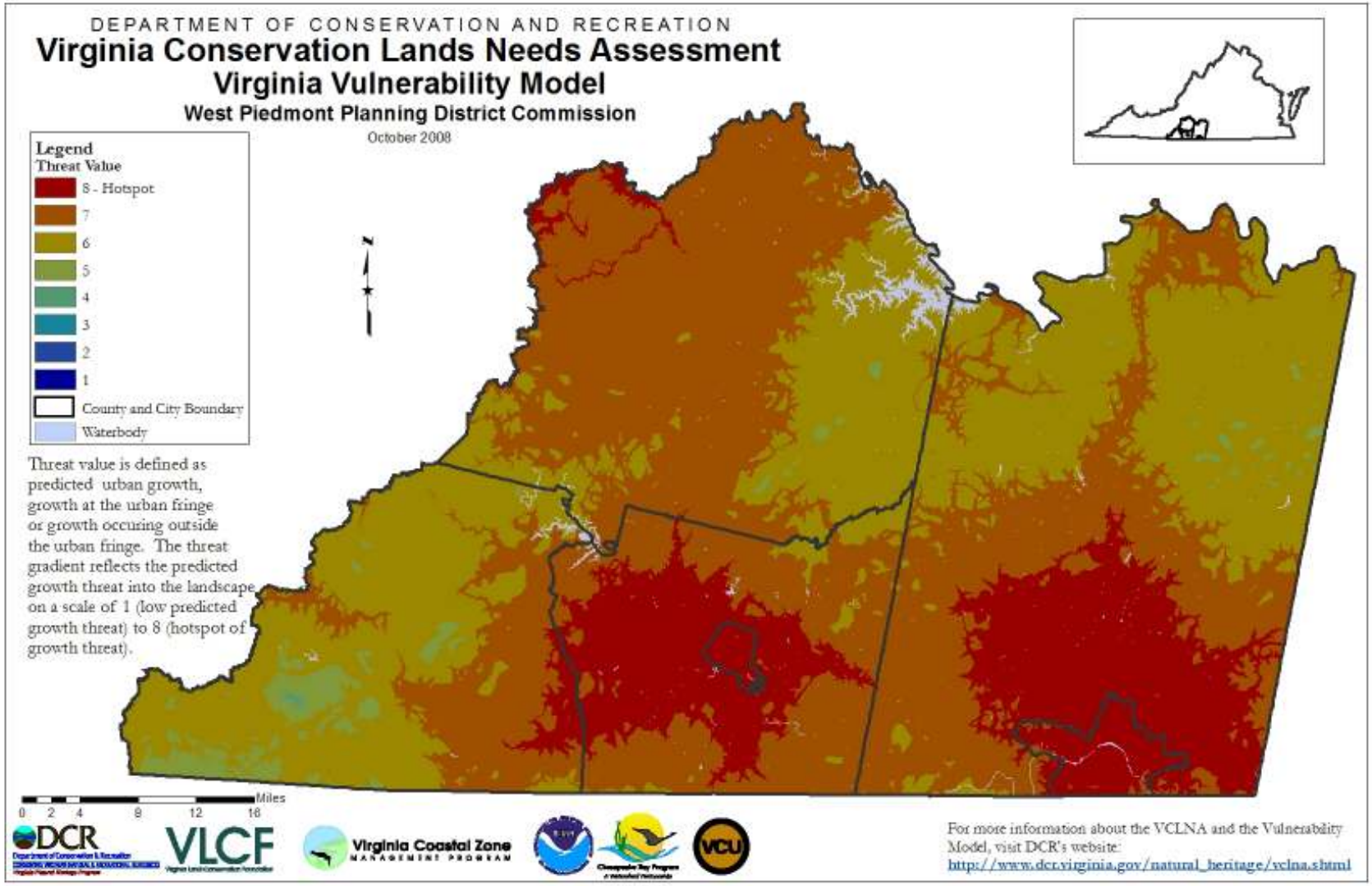

Figure 46. PDC 12 West Piedmont Planning District Commission Urban Vulnerability Model.

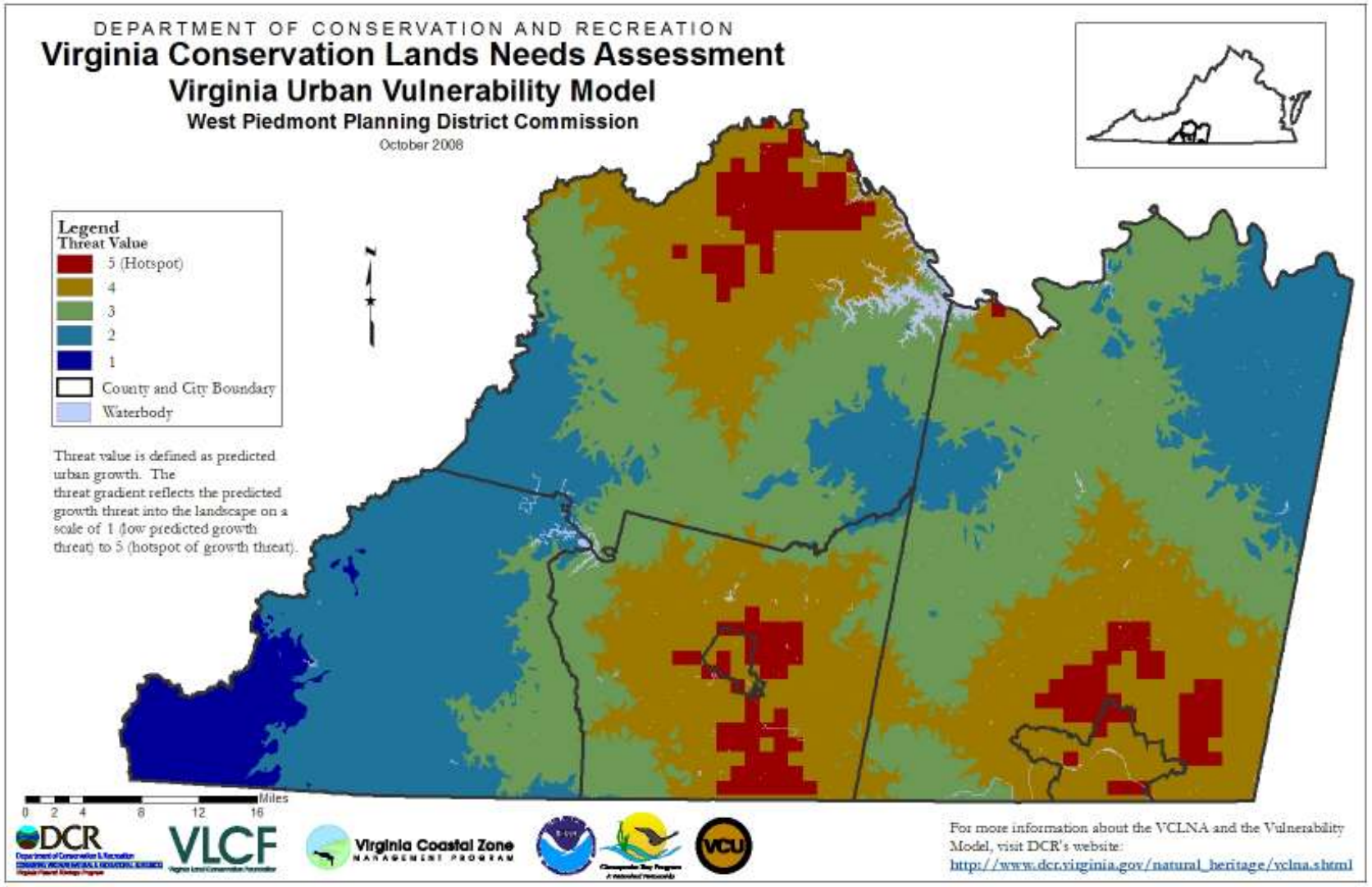

Figure 47. PDC 12 West Piedmont Planning District Commission Urban Fringe Vulnerability Model.

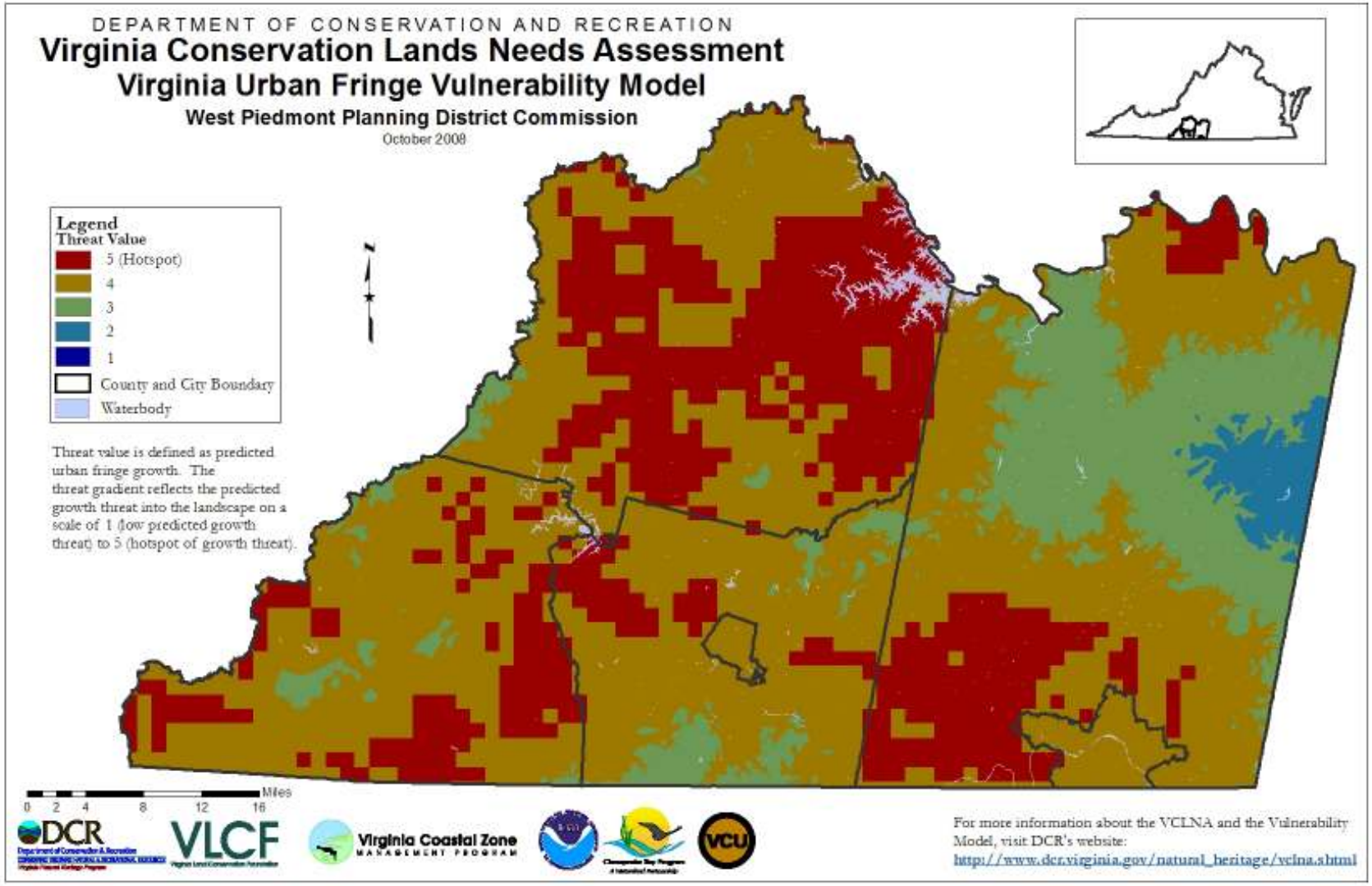

Figure 48. PDC 12 West Piedmont Planning District Commission Outside the Urban Fringe Vulnerability Model.

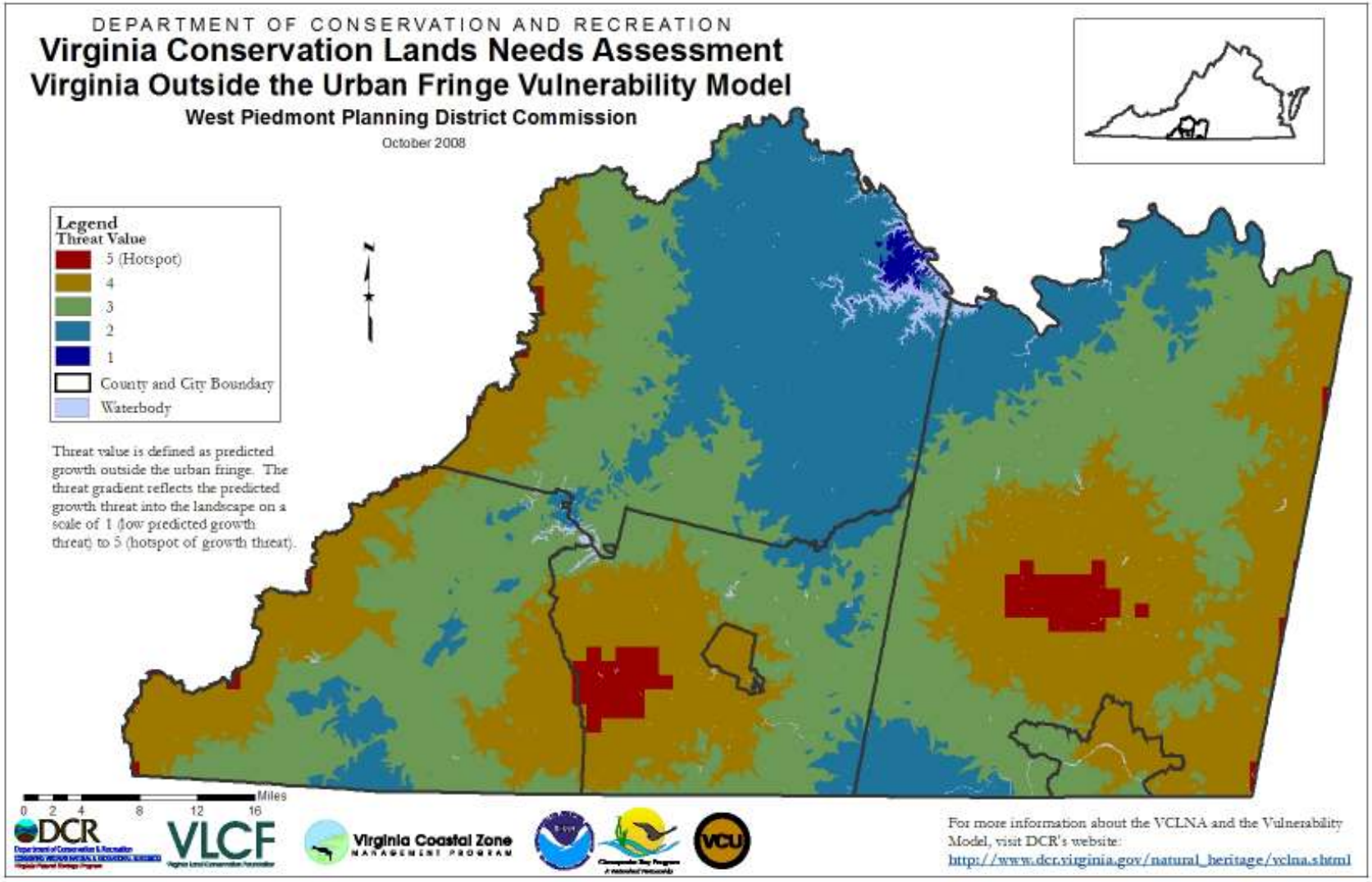

Figure 49. PDC 13 Southside Planning District Commission Vulnerability Model.

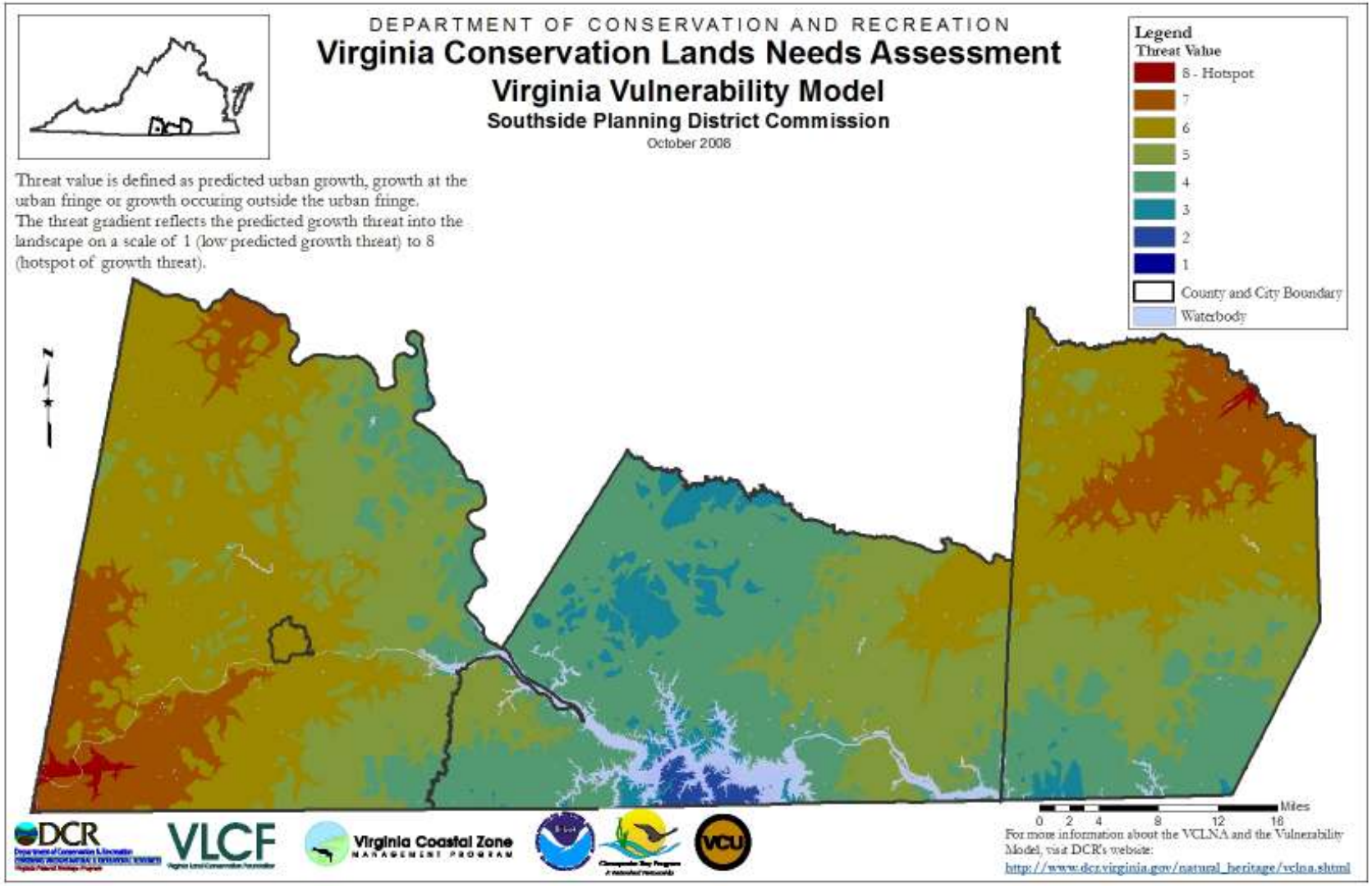

Figure 50. PDC 13 Southside Planning District Commission Urban Vulnerability Model.

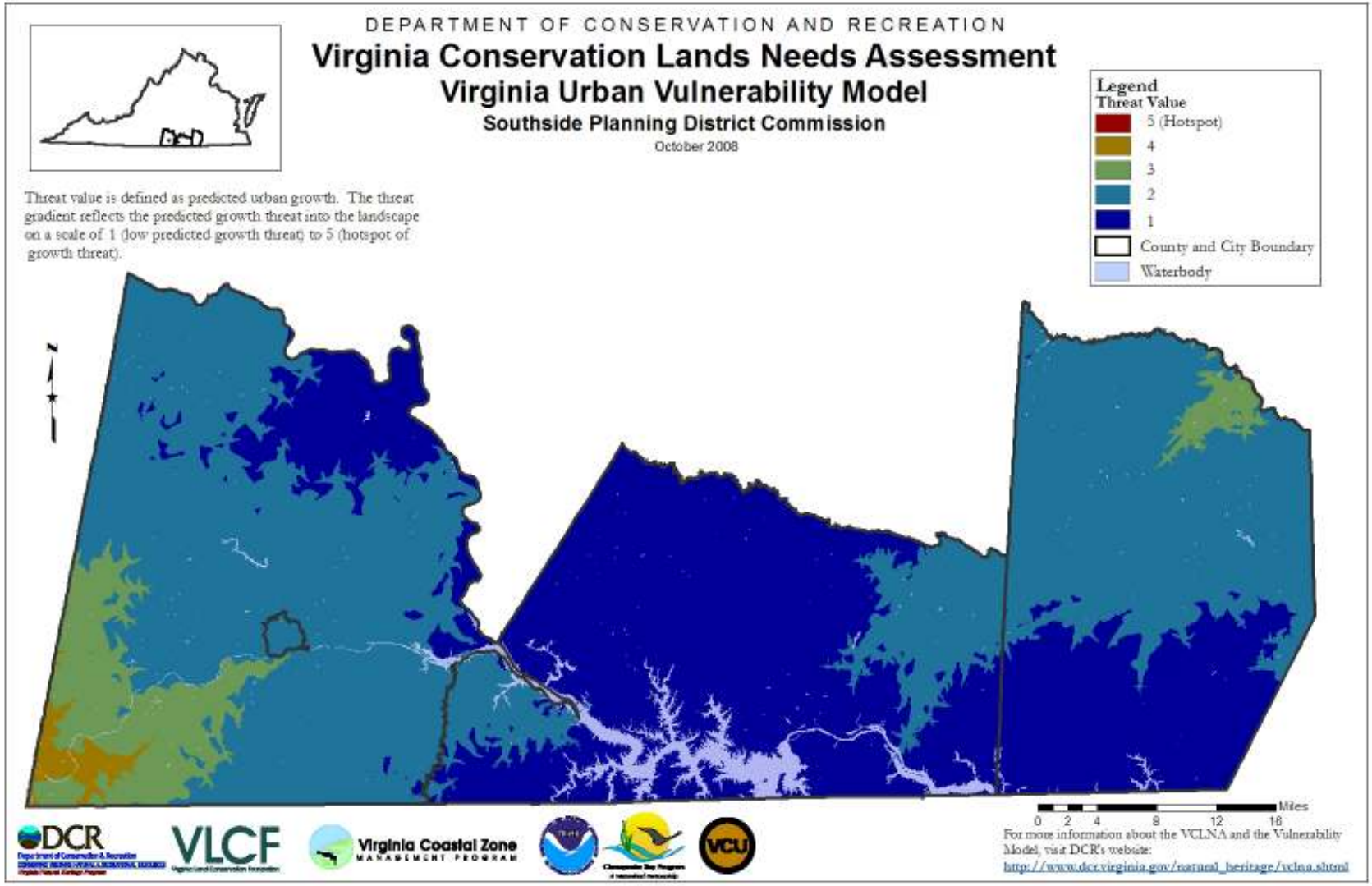

Figure 51. PDC 13 Southside Planning District Commission Urban Fringe Vulnerability Model.

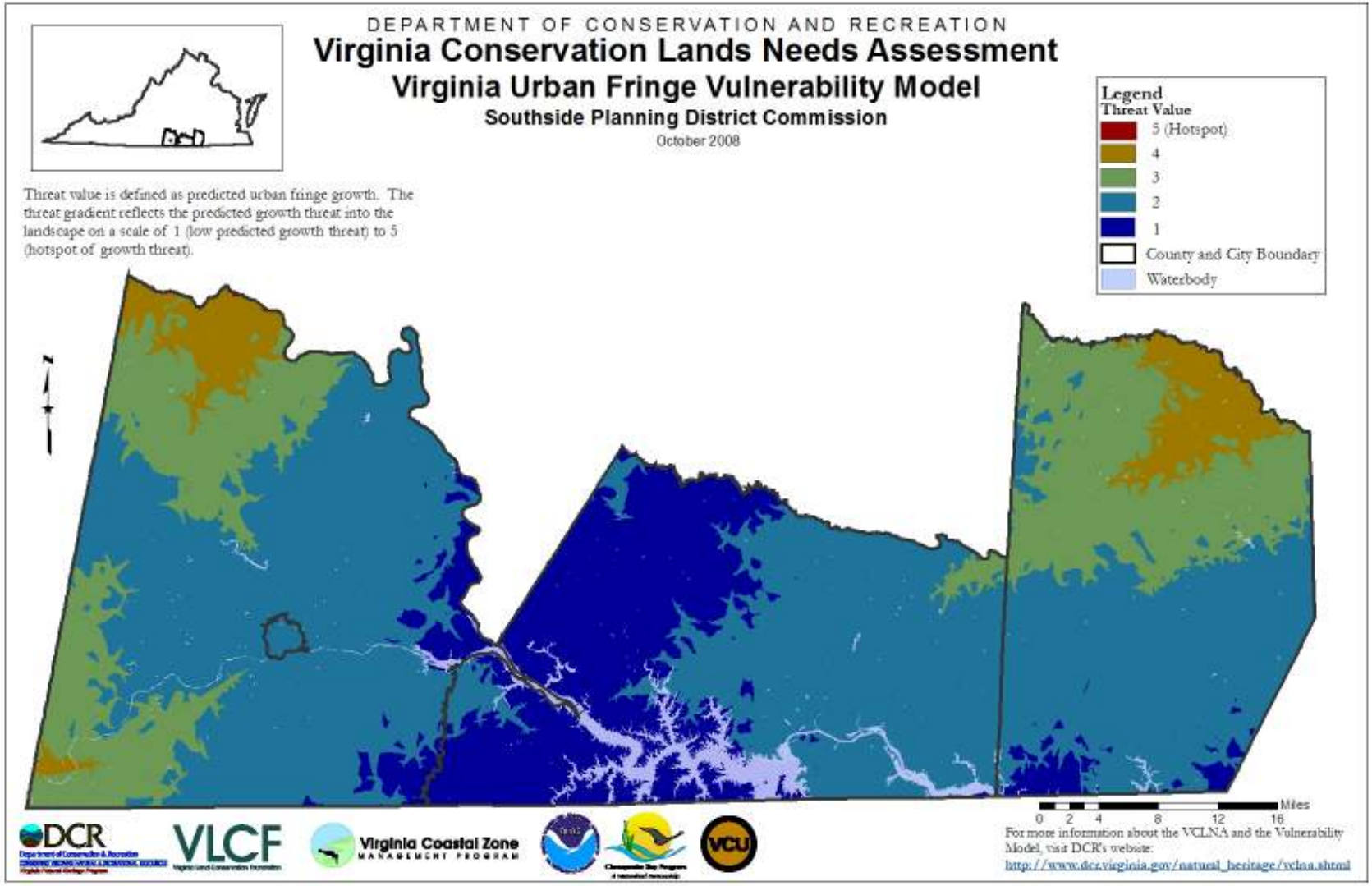

Figure 52. PDC 13 Southside Planning District Commission Outside the Urban Fringe Vulnerability Model.

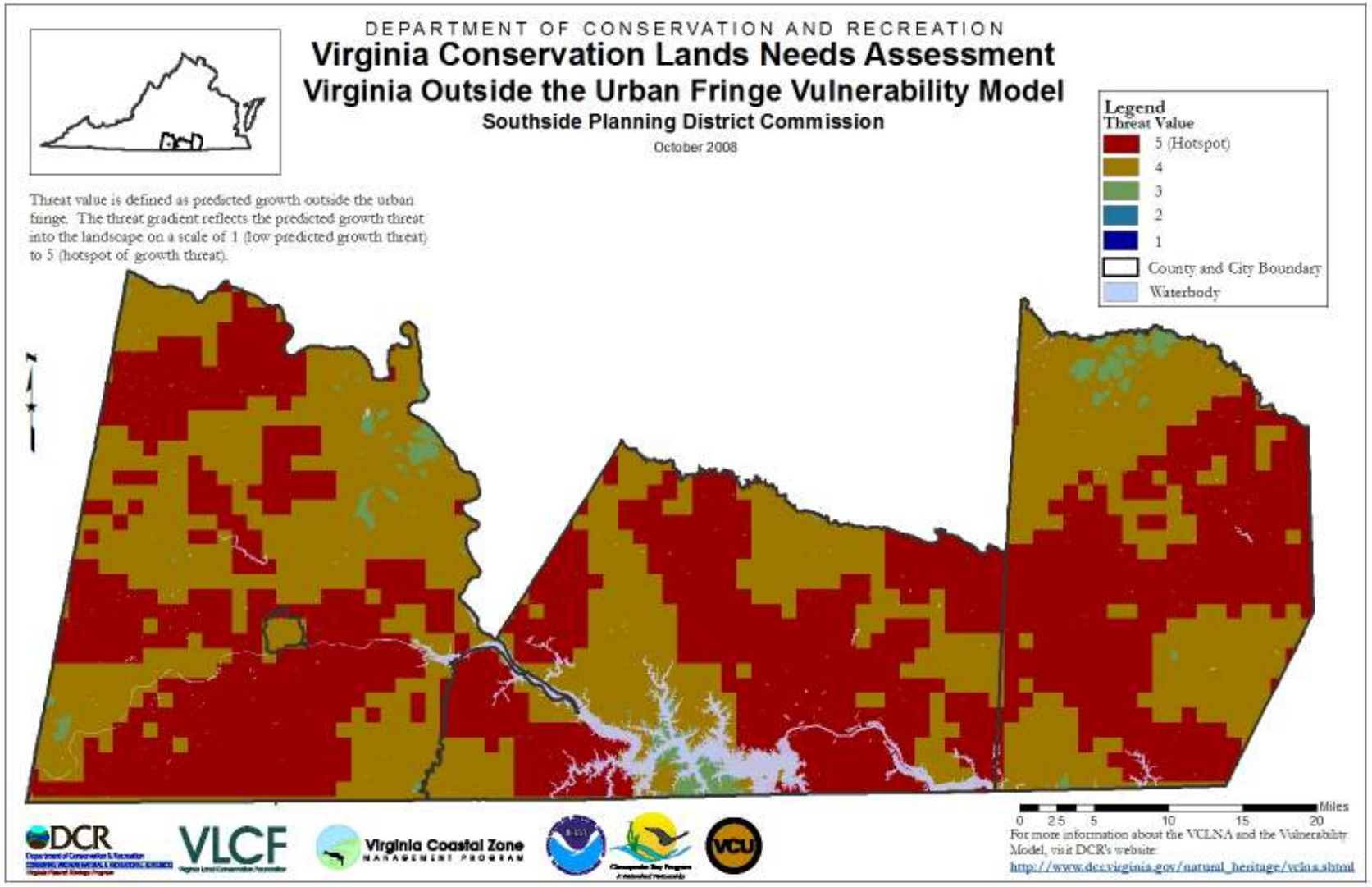

Figure 53. PDC 14 Commonwealth Regional Council Vulnerability Model.

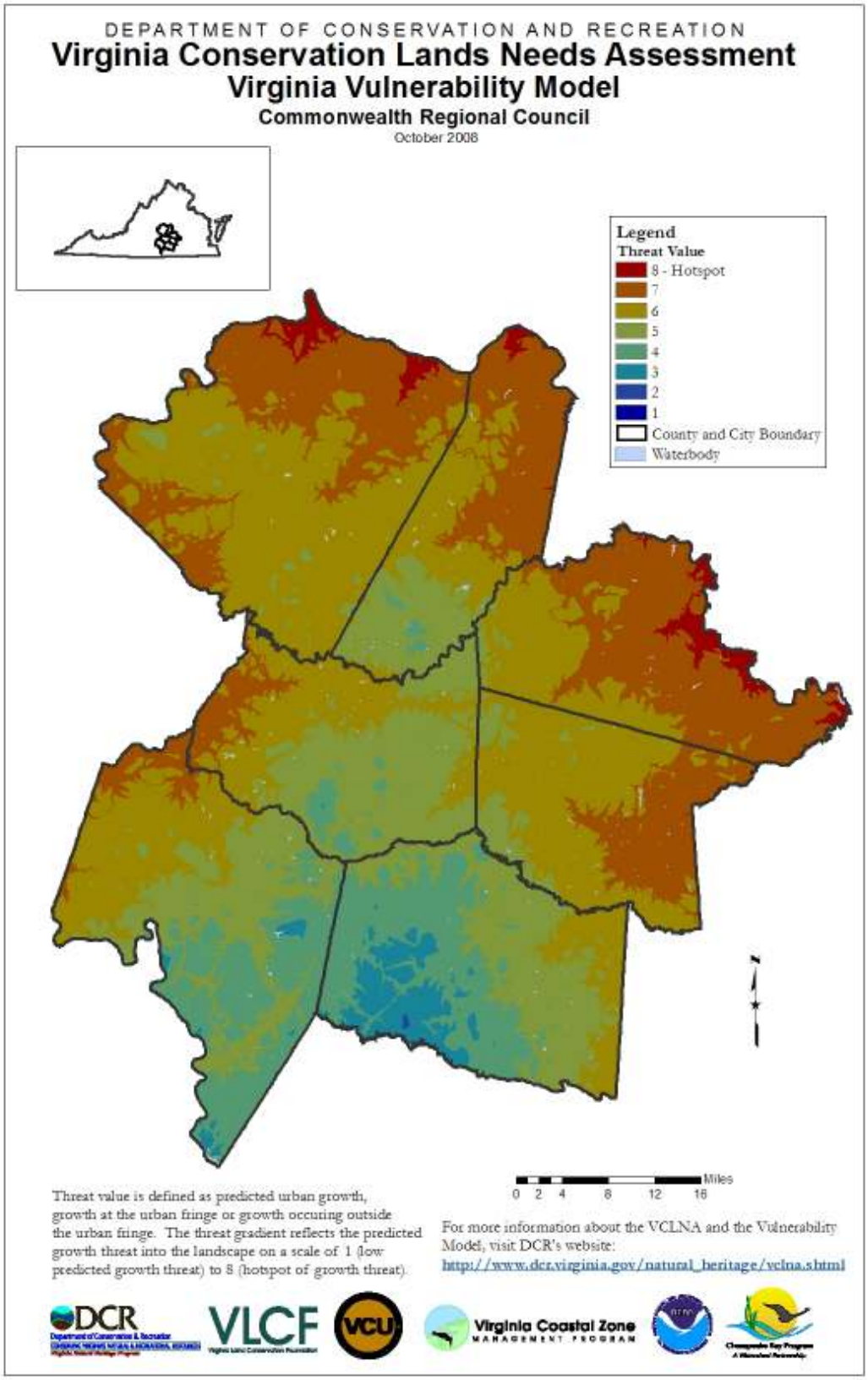

Figure 54. DC 14 Commonwealth Regional Council Urban Vulnerability Model.

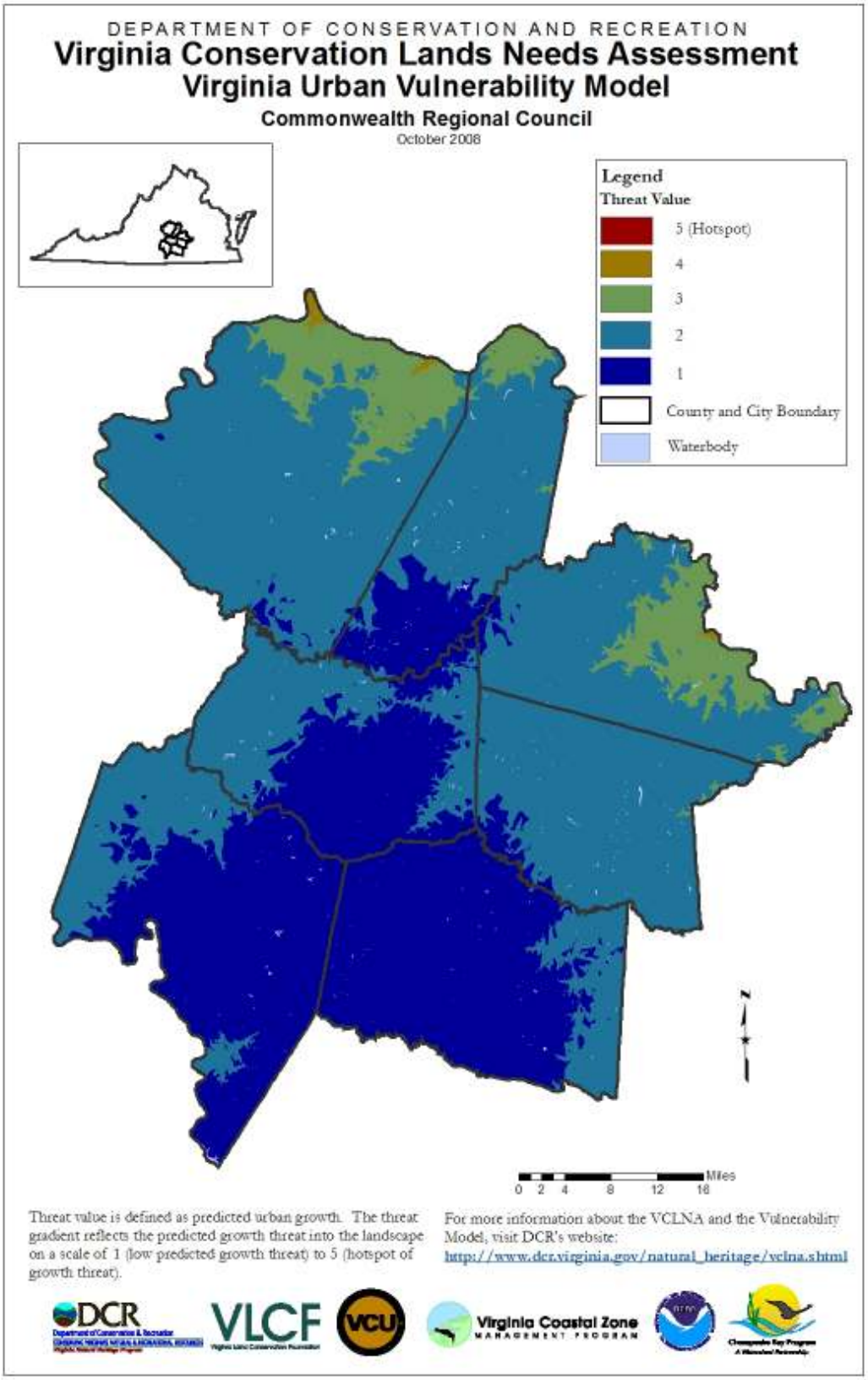

Figure 55. PDC 14 Commonwealth Regional Council Urban Fringe Vulnerability Model.

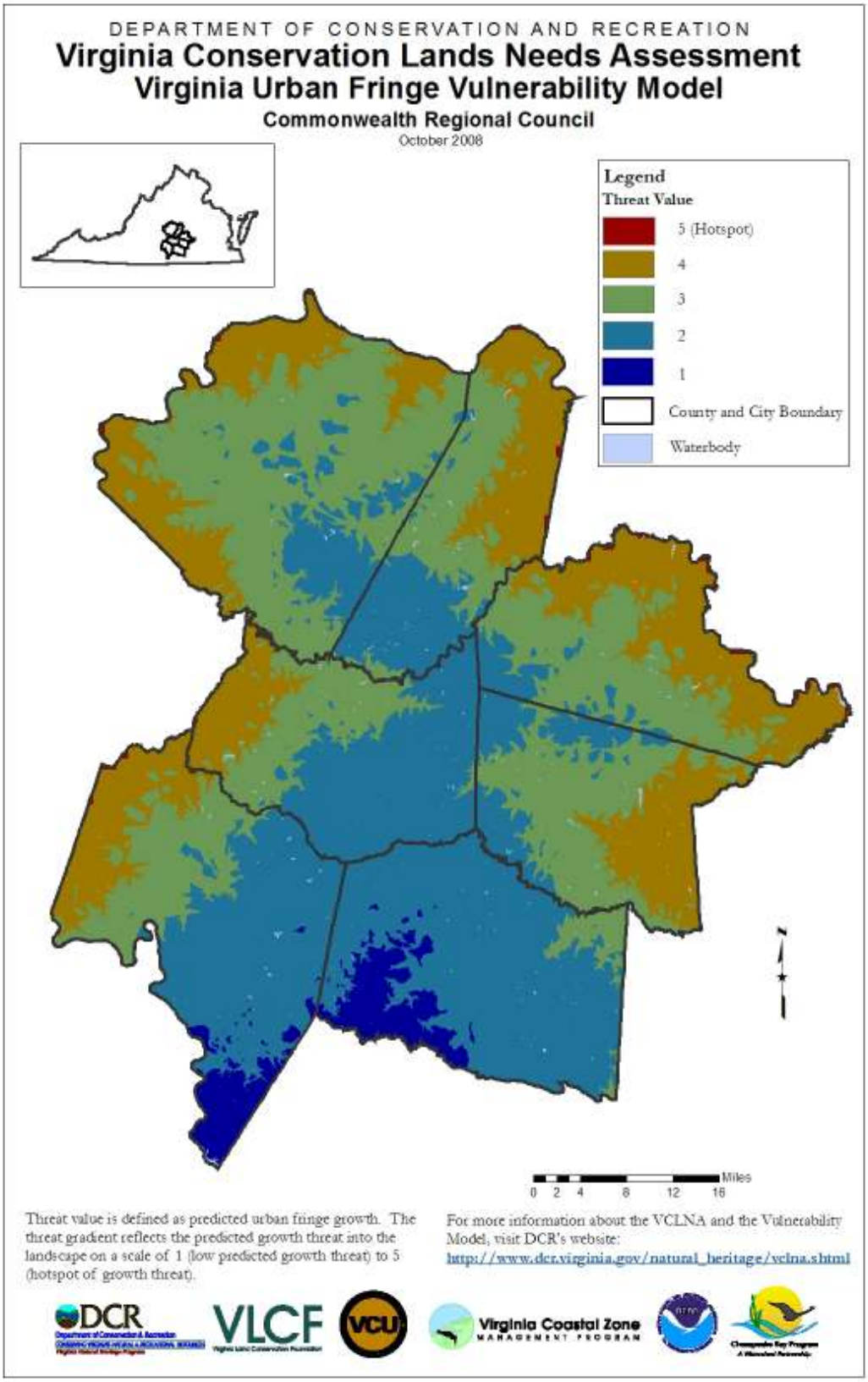

Figure 56. PDC 14 Commonwealth Regional Council Growth Outside the Urban Fringe Vulnerability Model.

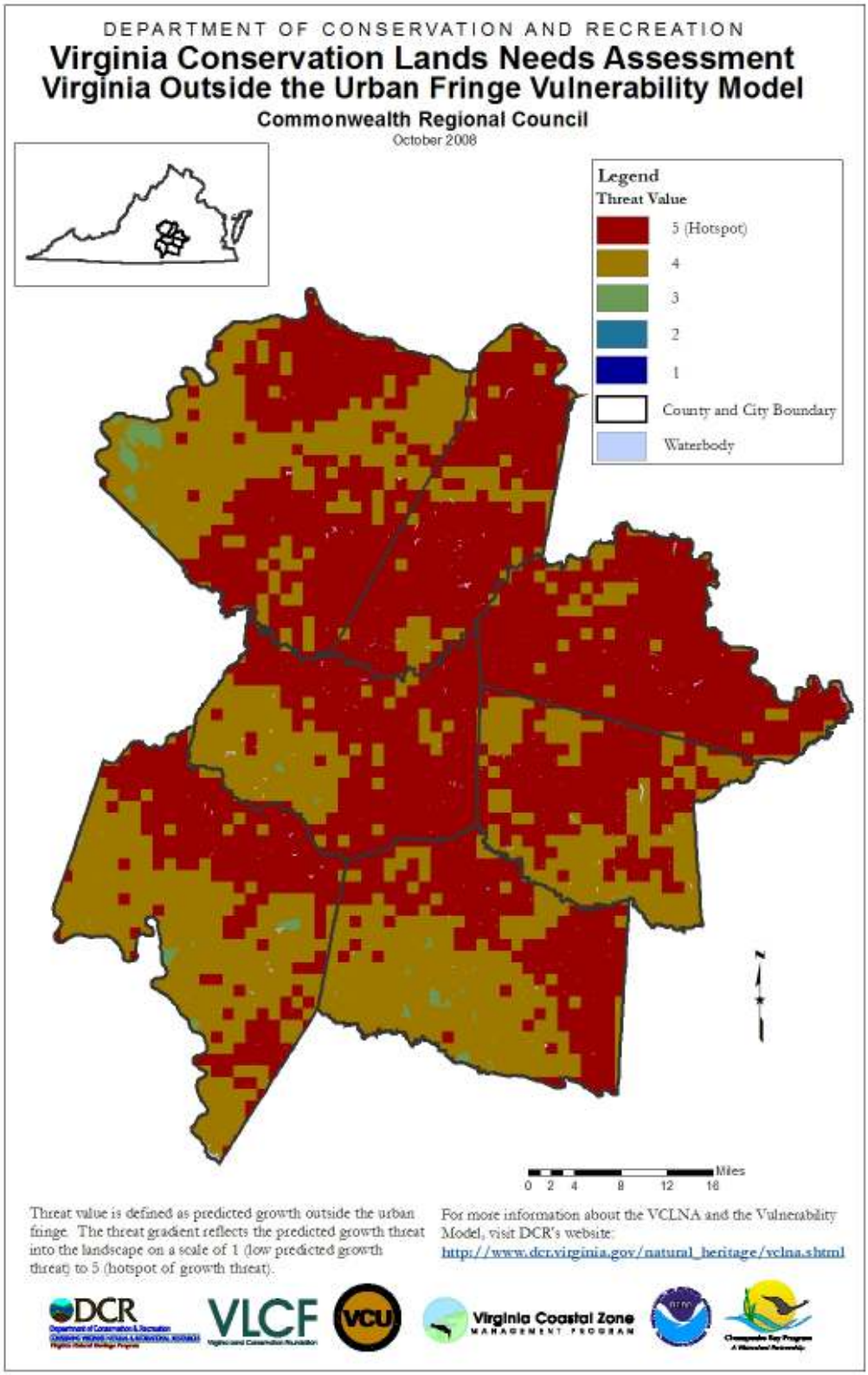

Figure 57. PDC 15 Richmond Regional Vulnerability Model.

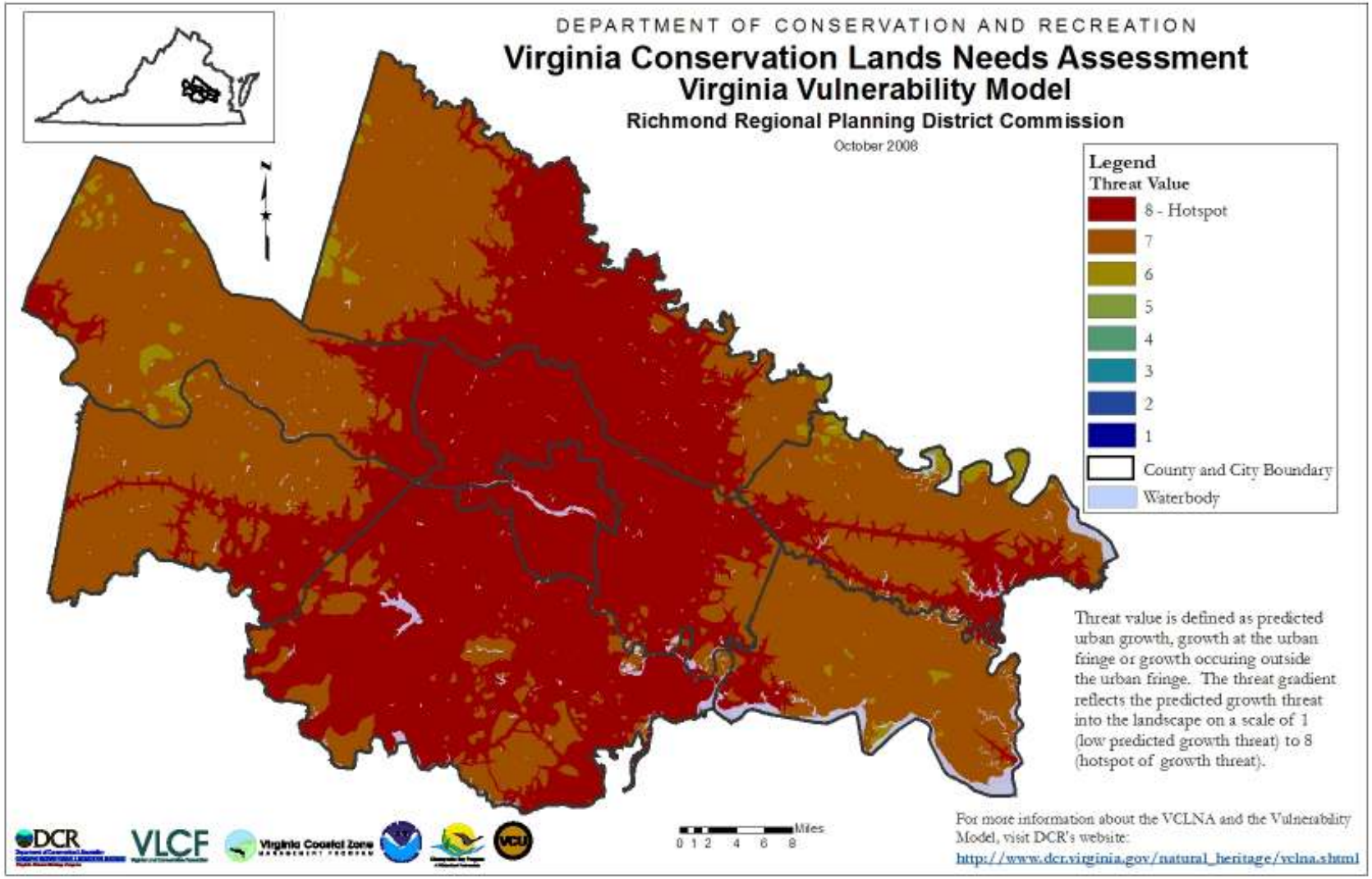

Figure 58. PDC 15 Richmond Regional Urban Vulnerability Model.

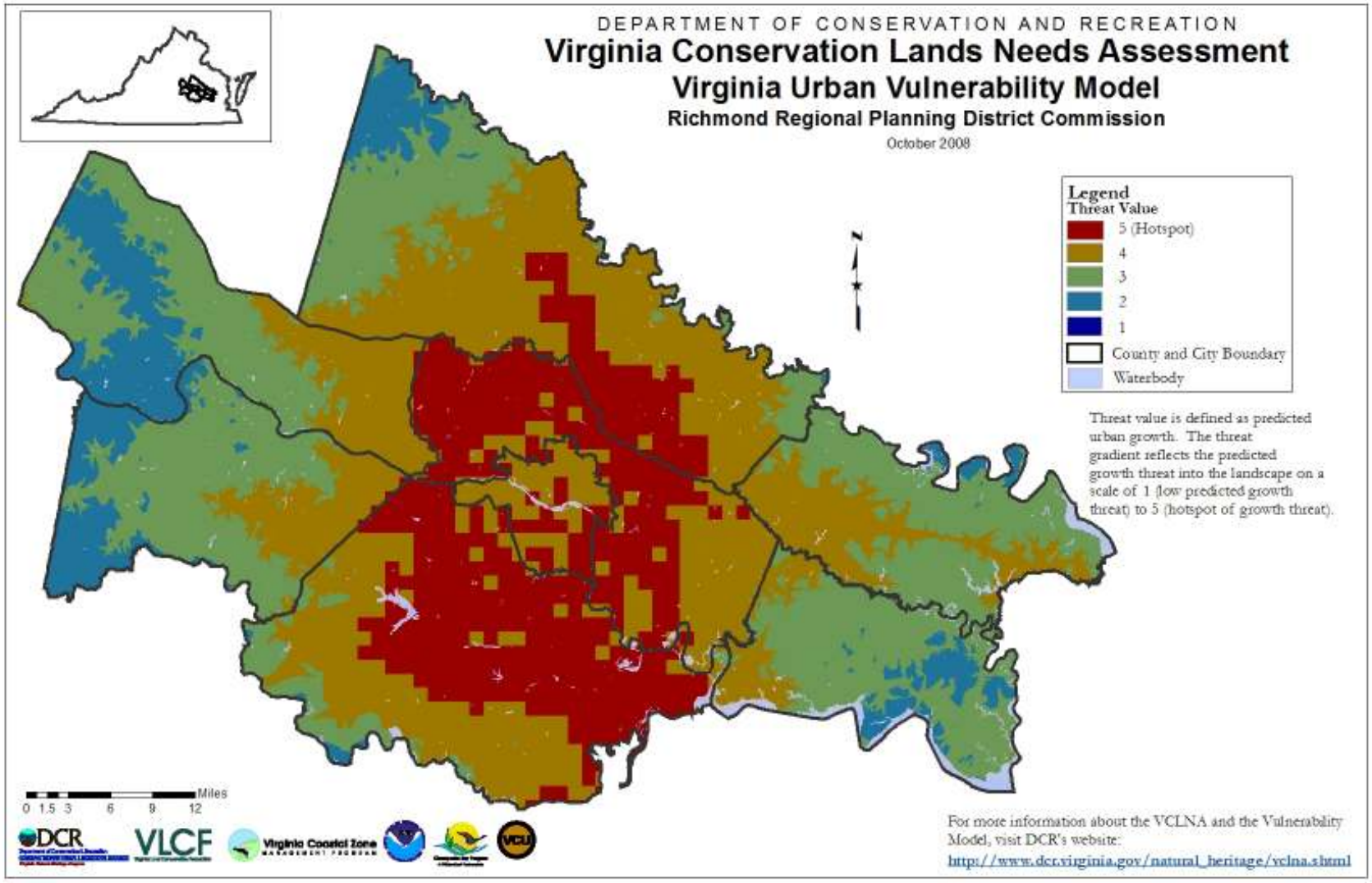

Figure 59. PDC 15 Richmond Regional Urban Fringe Vulnerability Model.

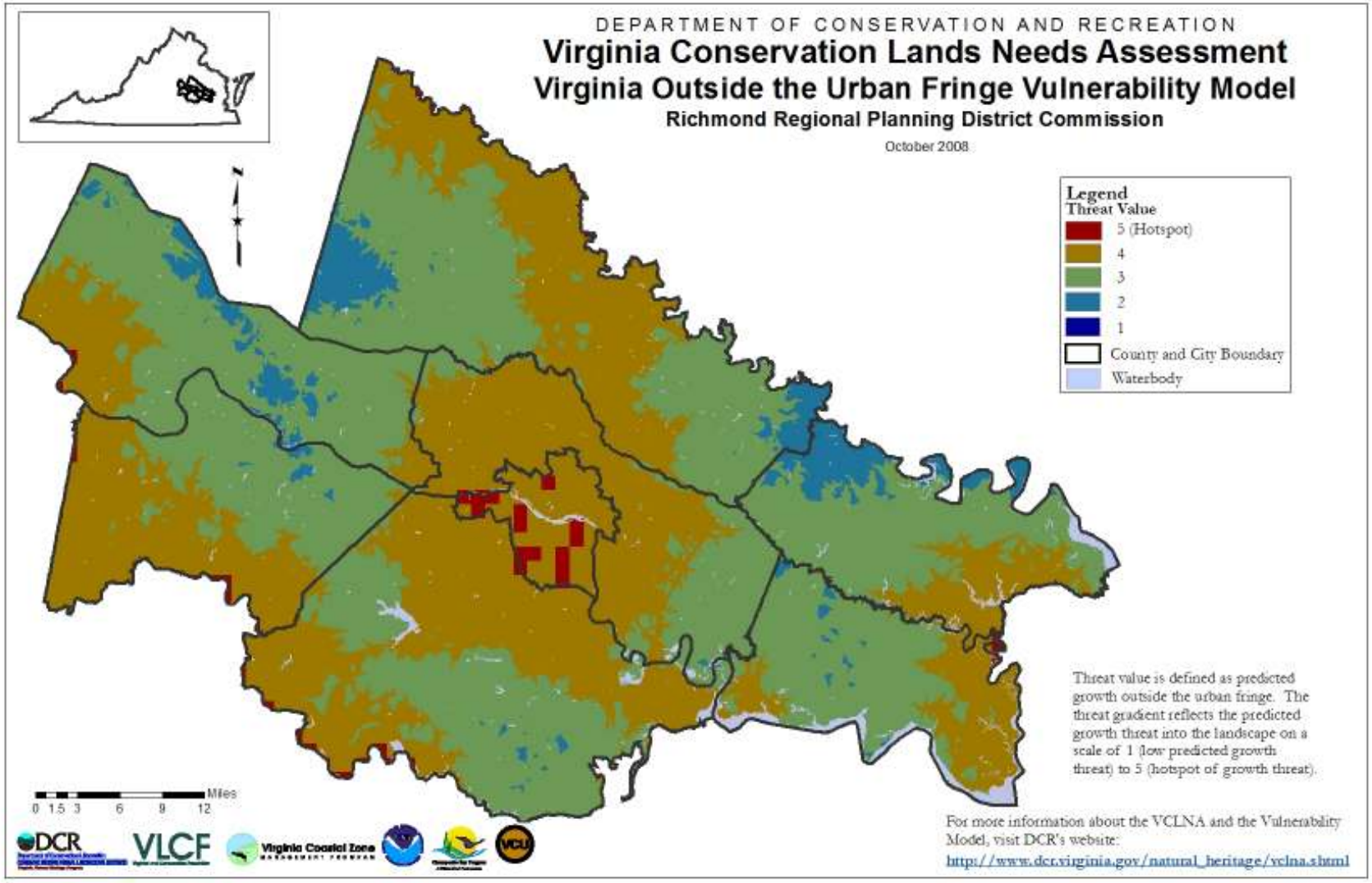

Figure 60. PDC 15 Richmond Regional Outside the Urban Fringe Vulnerability Model.

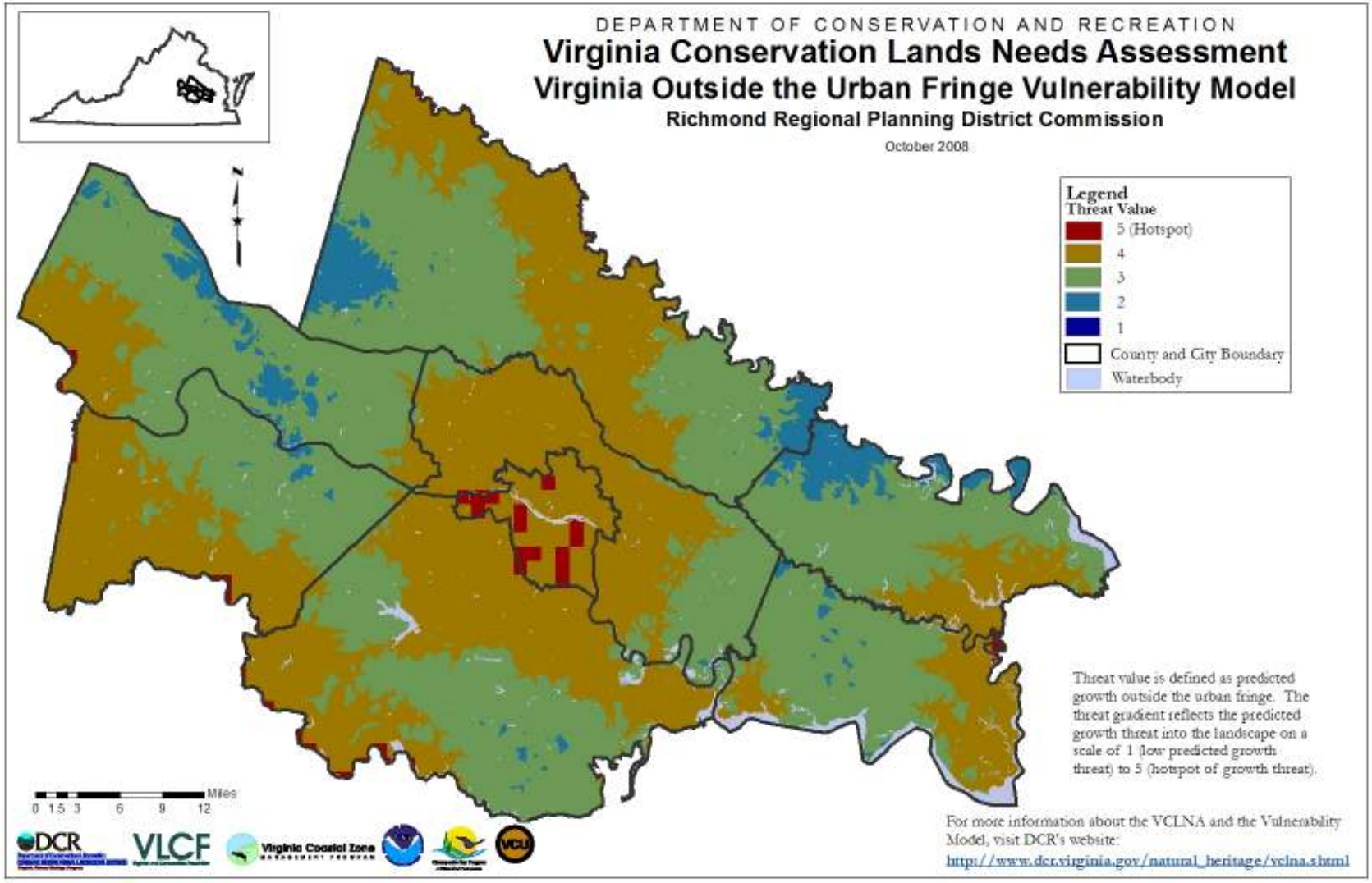

Figure 61. PDC 16 George Washington Regional Commission Vulnerability Model.

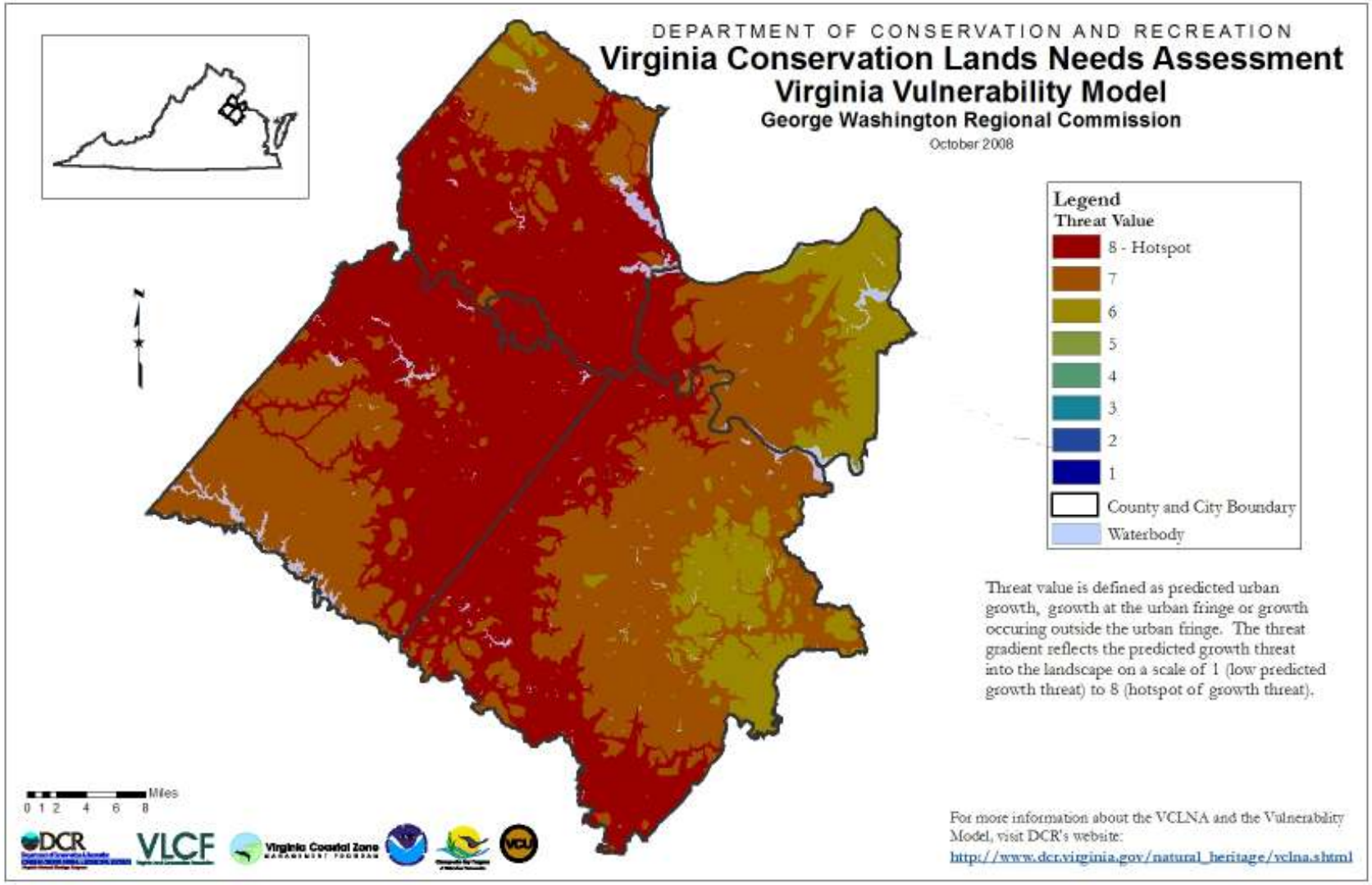

Figure 62. PDC 16 George Washington Regional Commission Urban Vulnerability Model.

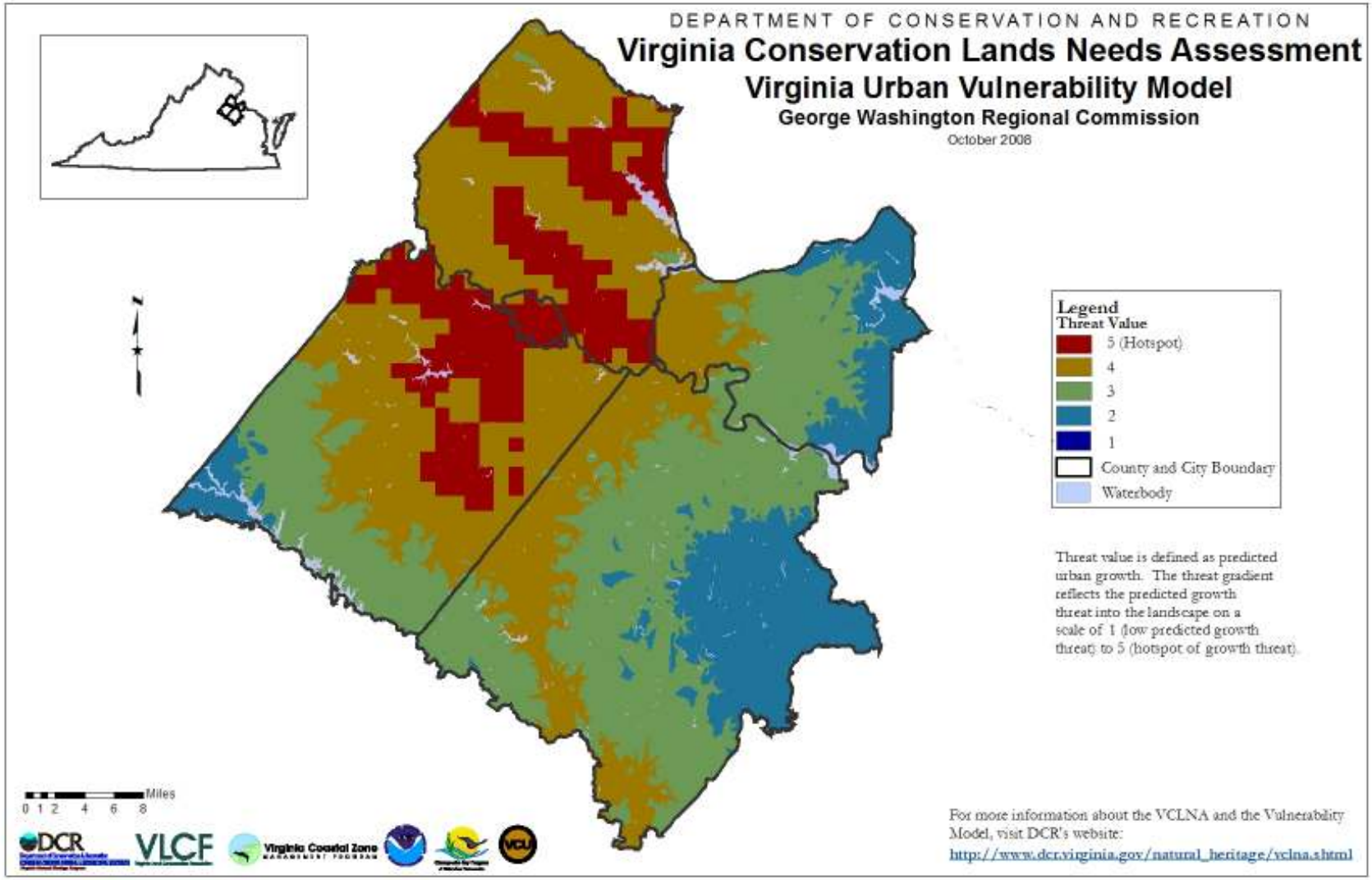

Figure 63. PDC 16 George Washington Regional Commission Urban Fringe Vulnerability Model.

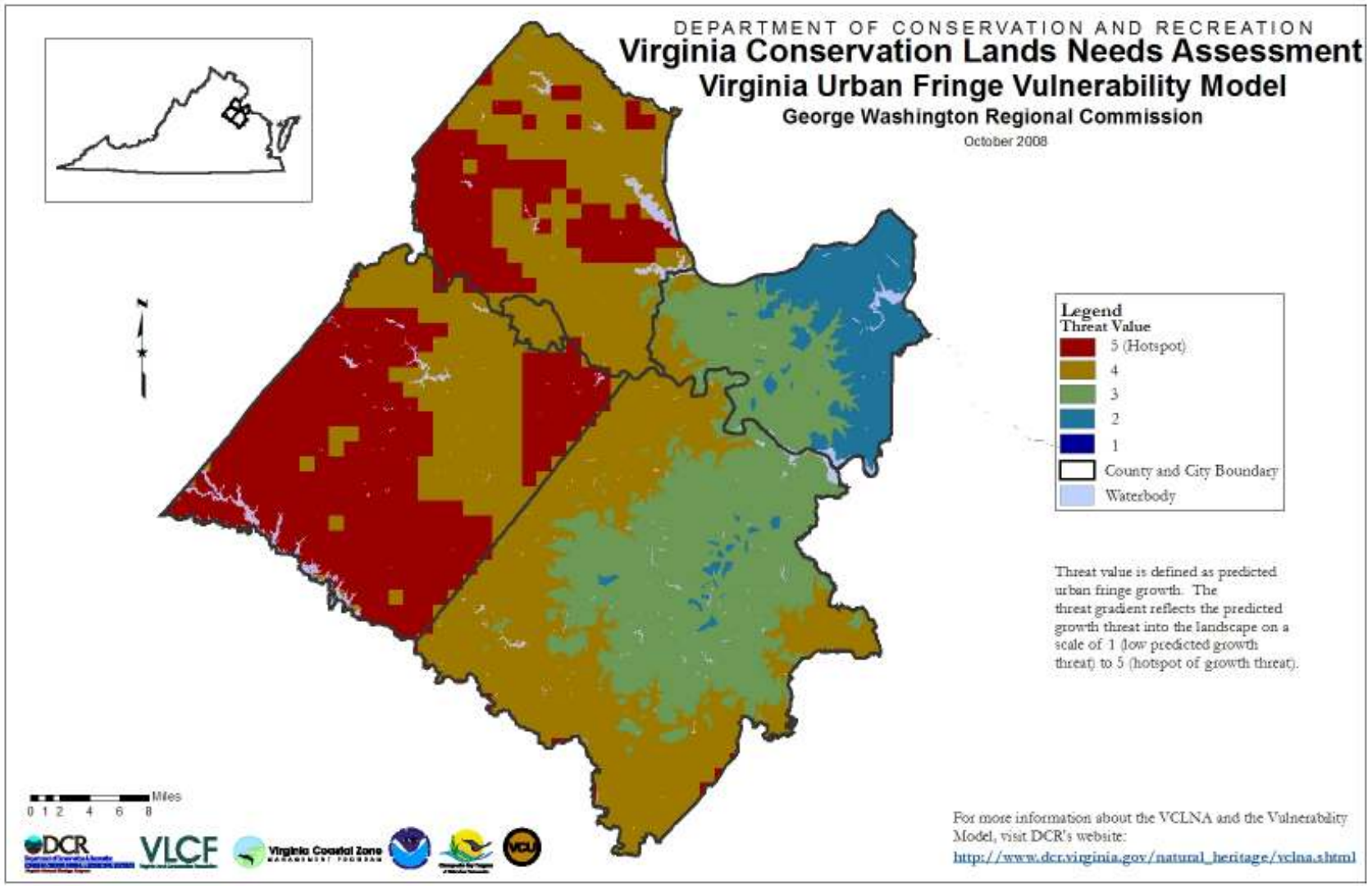

Figure 64. PDC 16 George Washington Regional Commission Outside the Urban Fringe Vulnerability Model.

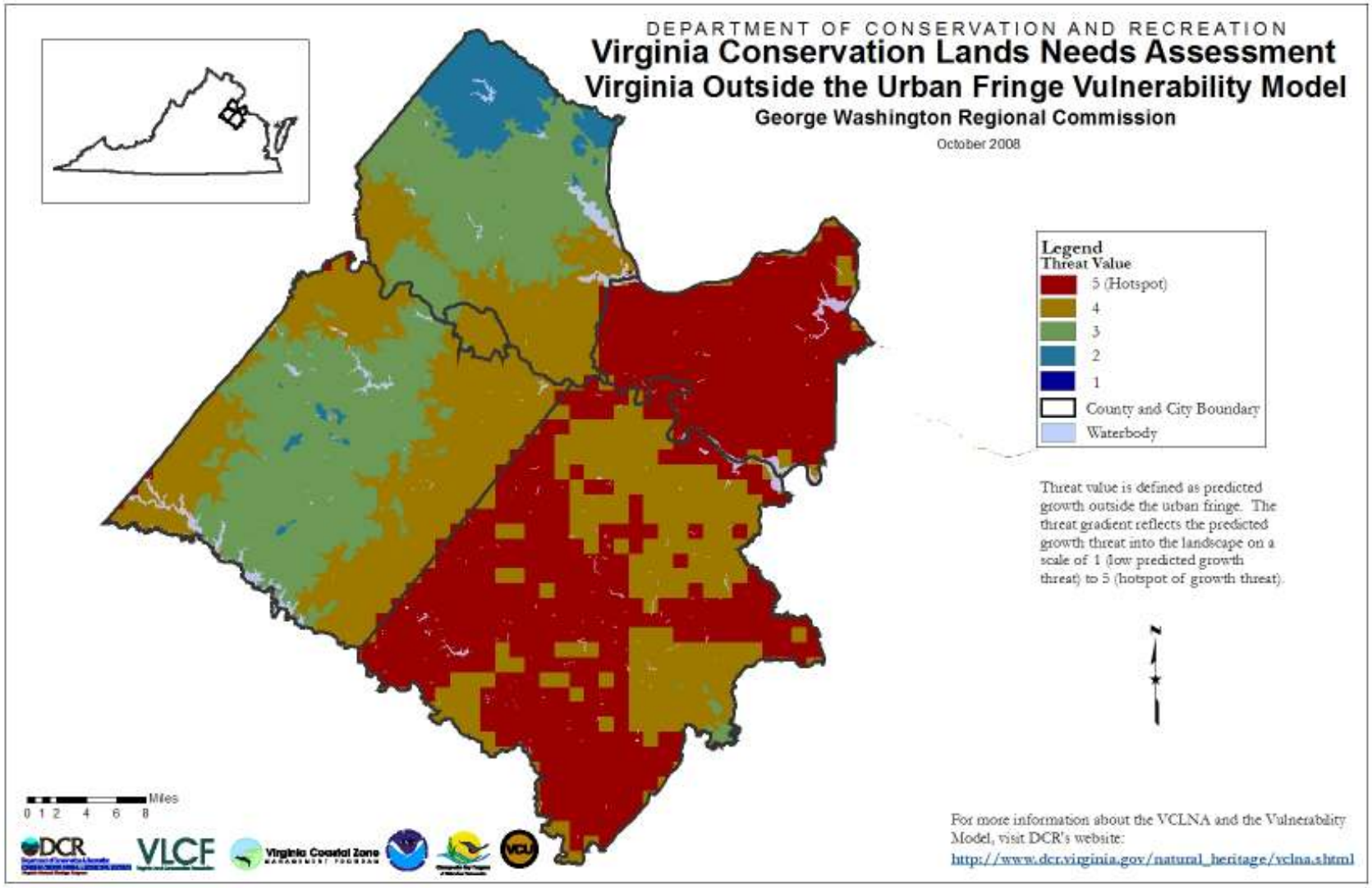

Figure 65. PDC 17 Northern Neck Vulnerability Model.

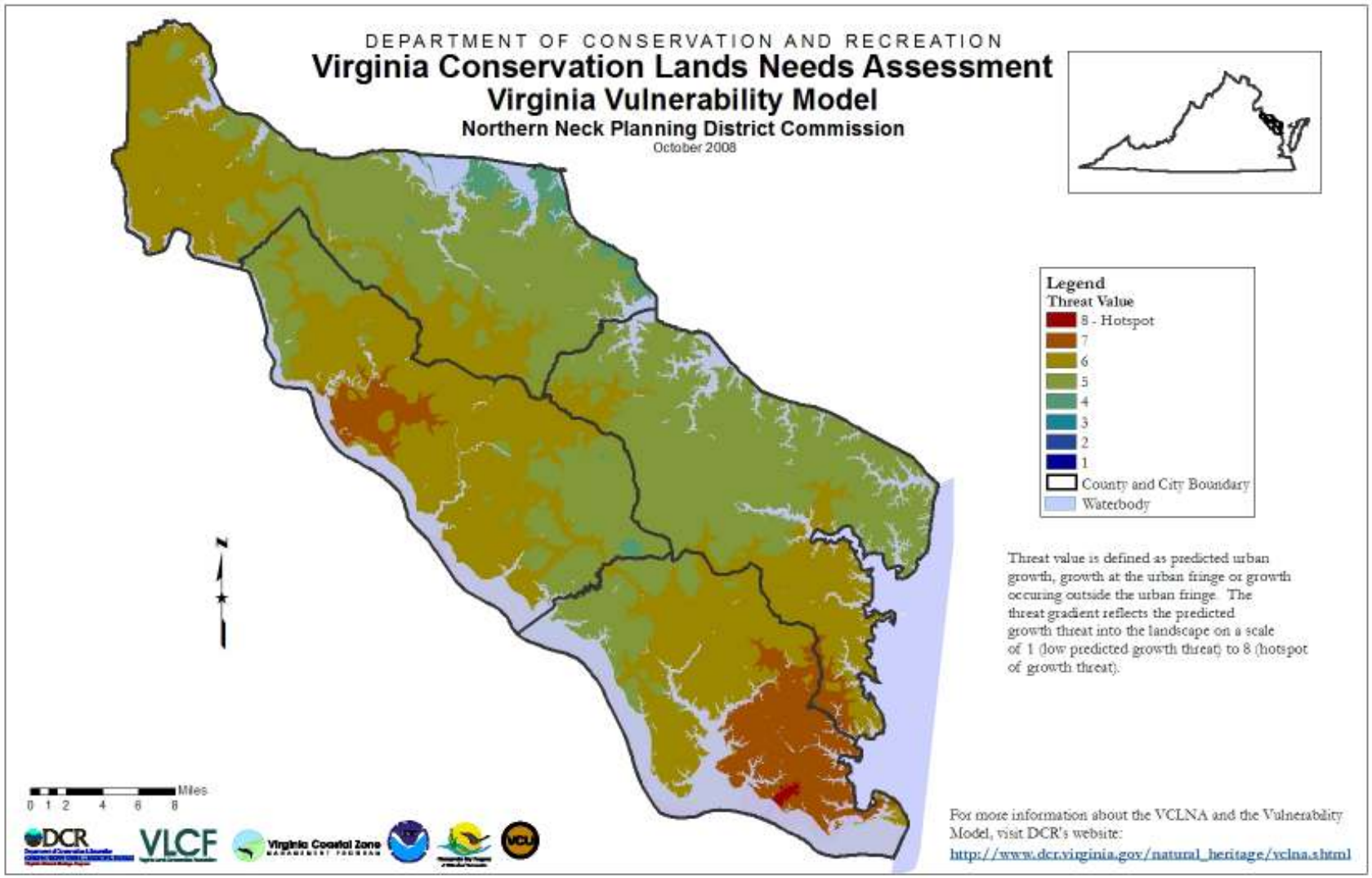

Figure 66. PDC 17 Northern Neck Urban Vulnerability Model.

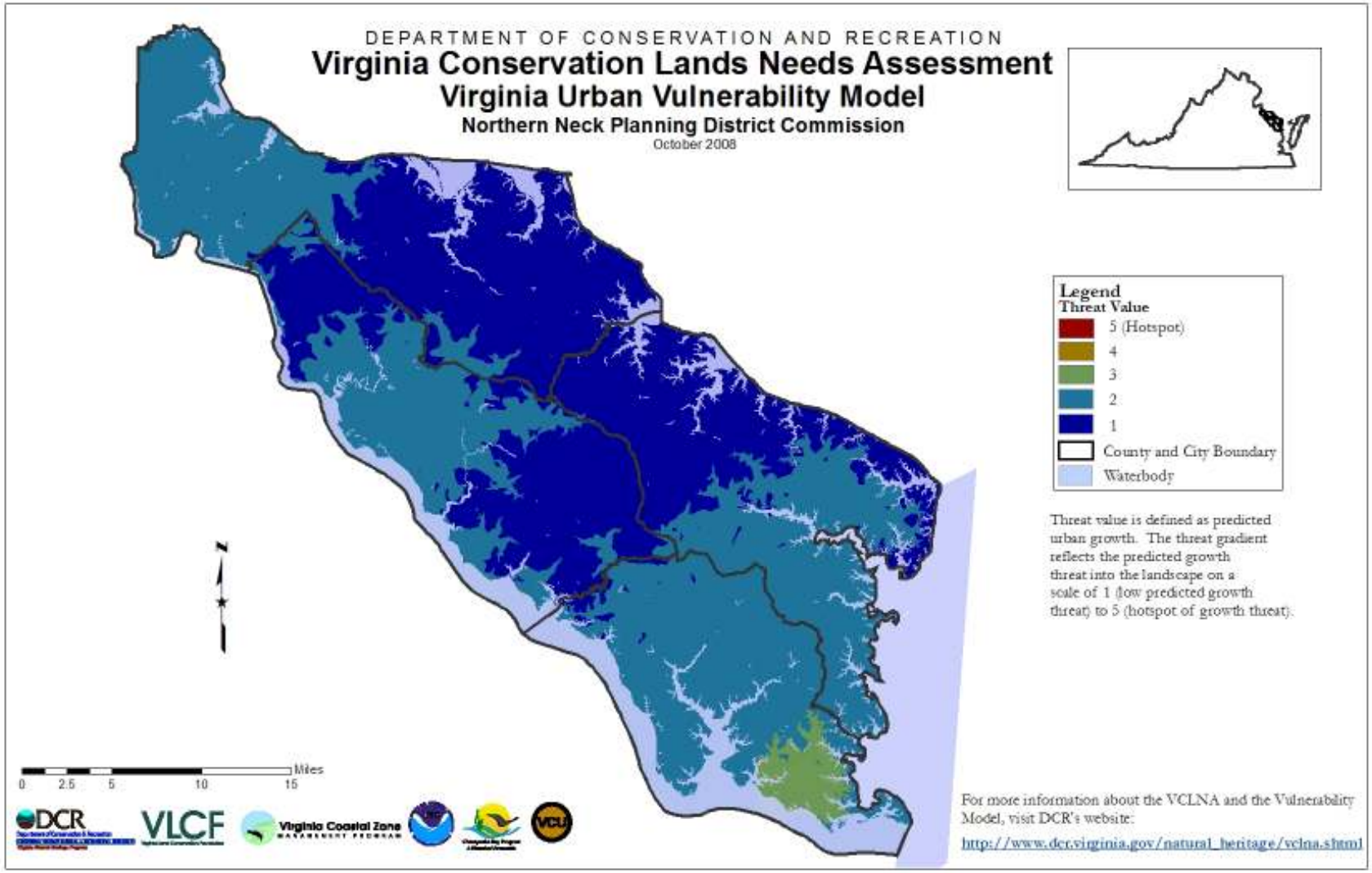

Figure 67. PDC 17 Northern Neck Urban Fringe Vulnerability Model.

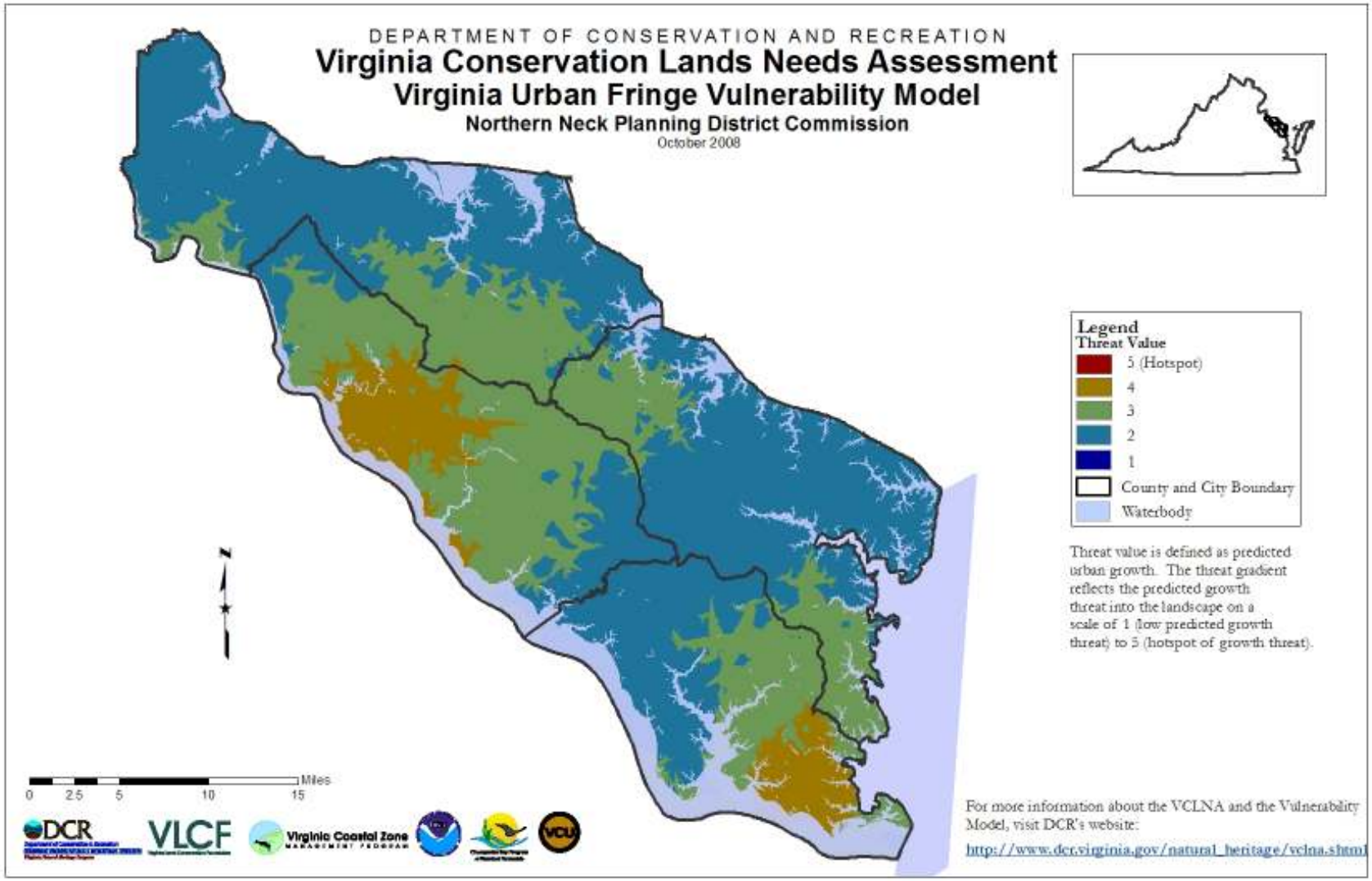

Figure 68. PDC 17 Northern Neck Outside the Urban Fringe Vulnerability Model.

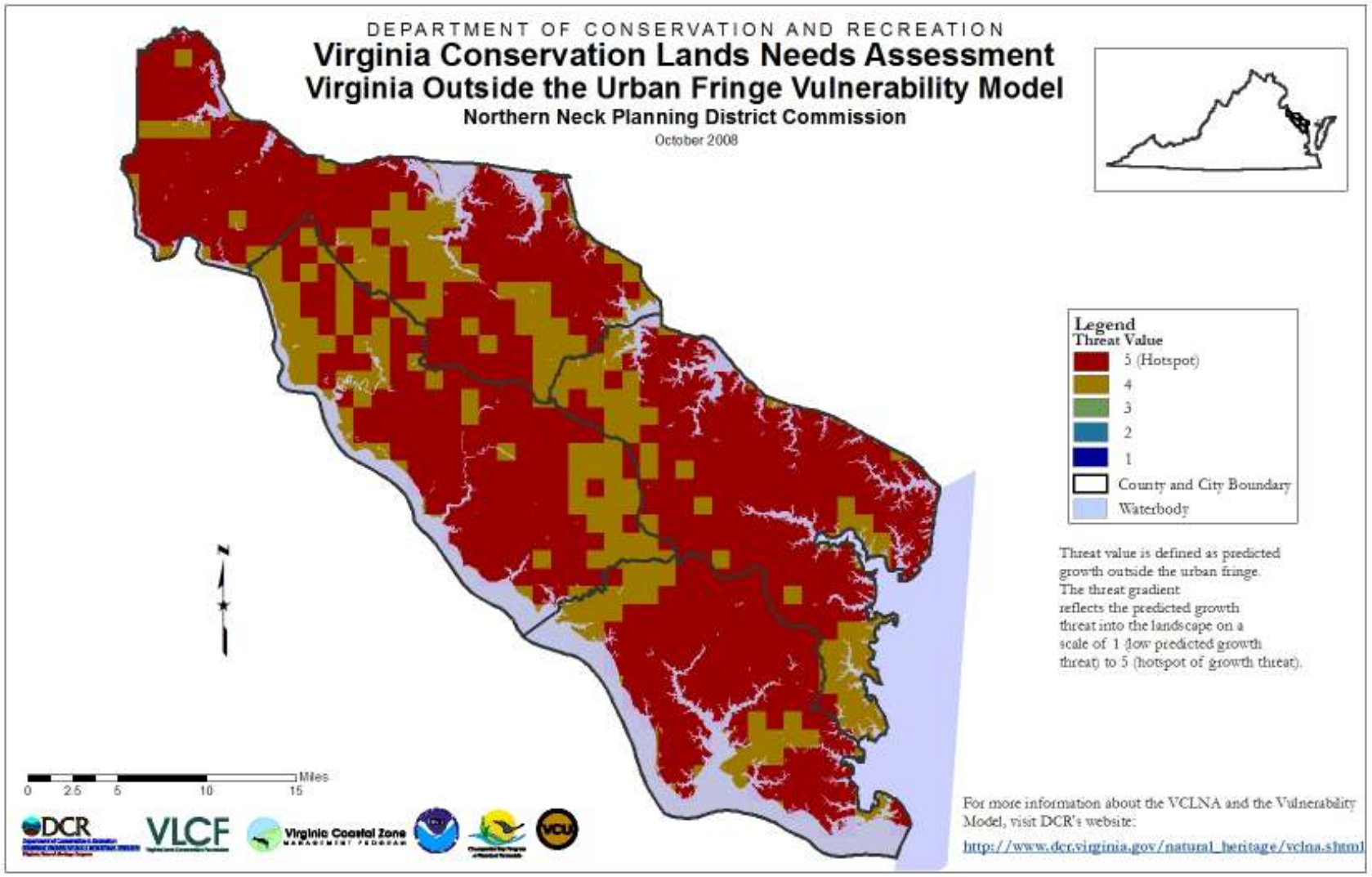

Figure 69. PDC 18 Middle Peninsula Vulnerability Model.

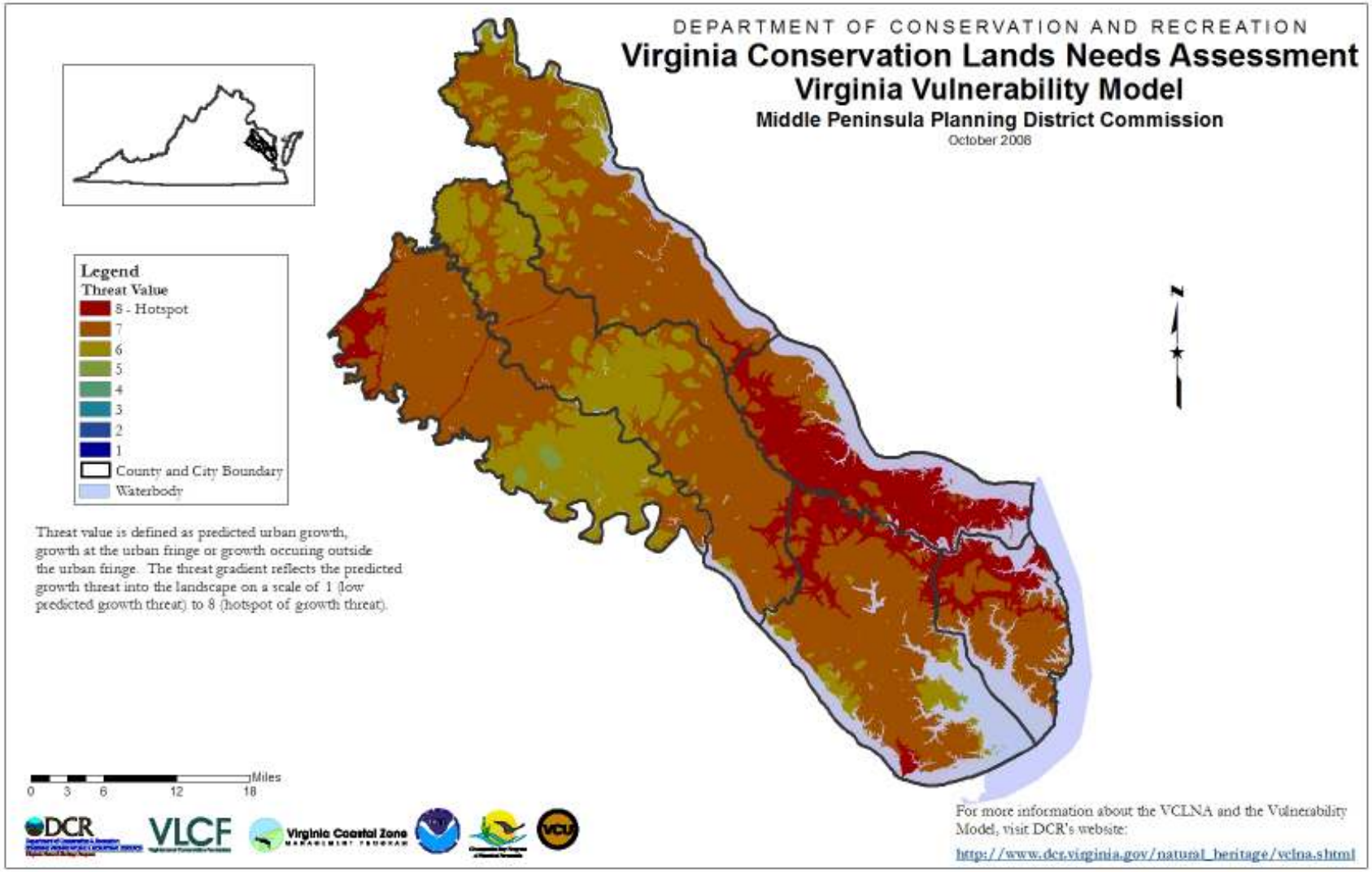

Figure 70. PDC 18 Middle Peninsula Urban Vulnerability Model.

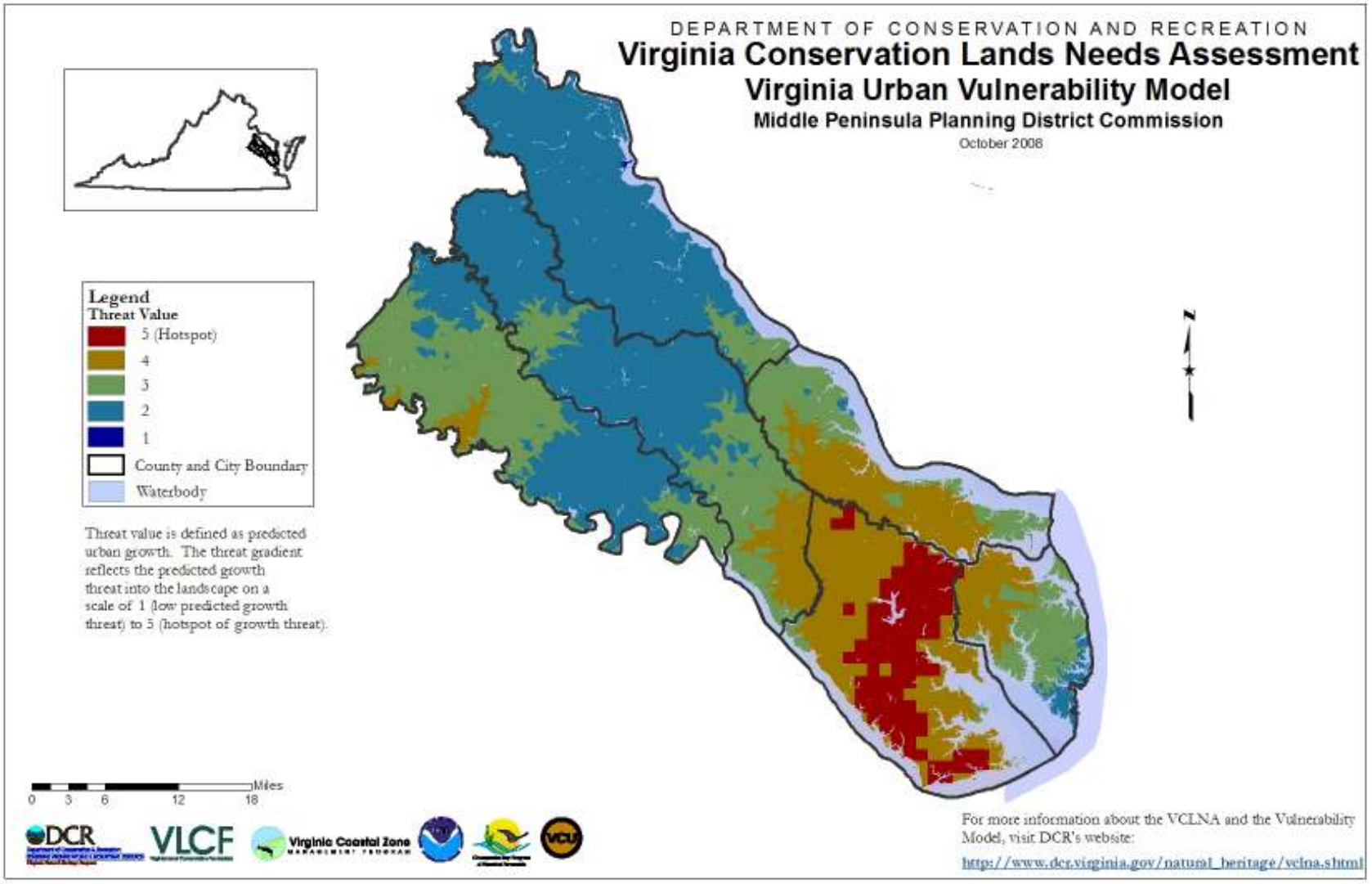

Figure 71. PDC 18 Middle Peninsula Urban Fringe Vulnerability Model.

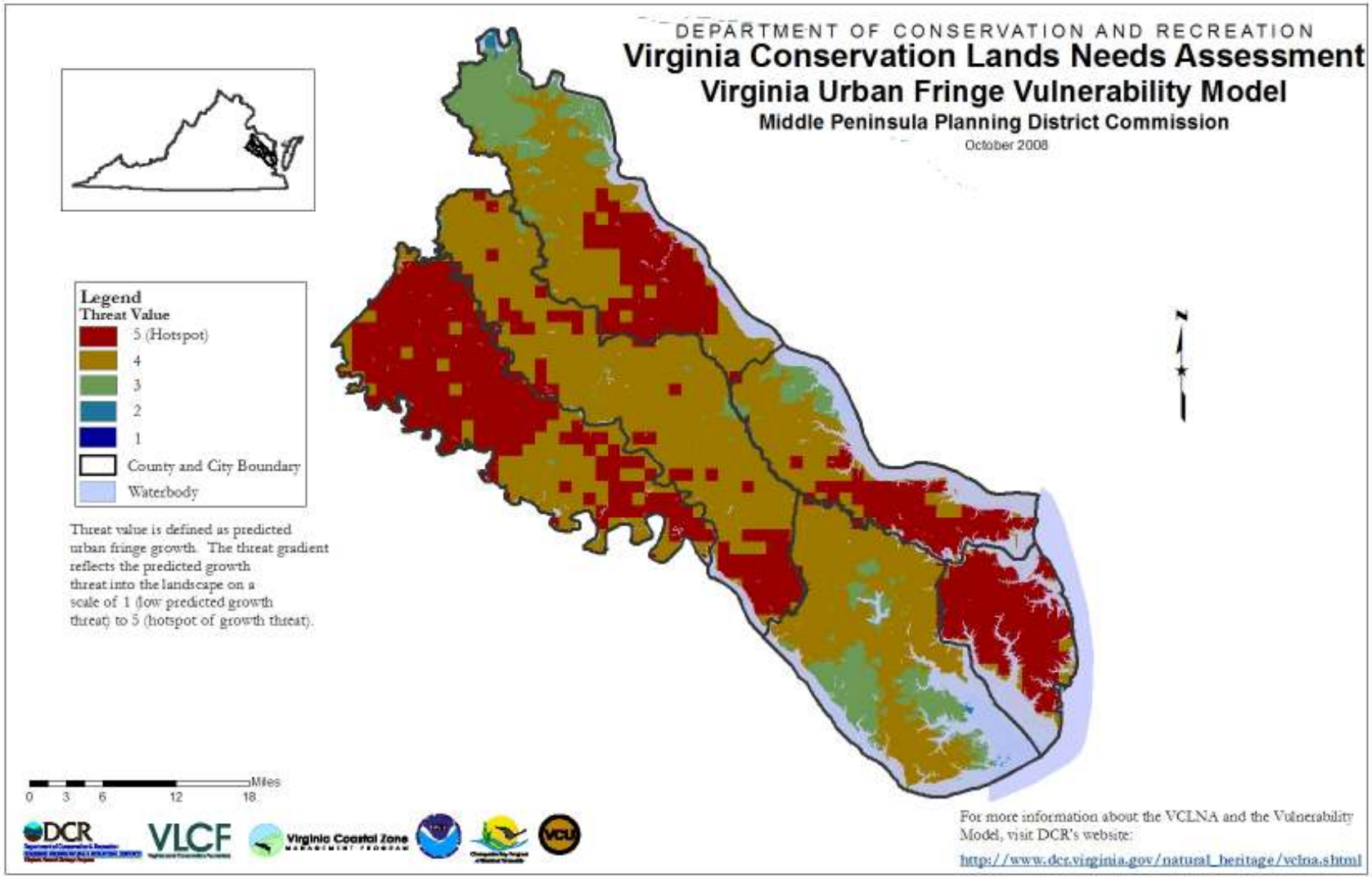

Figure 72. PDC 18 Middle Peninsula Outside the Urban Fringe Vulnerability Model.

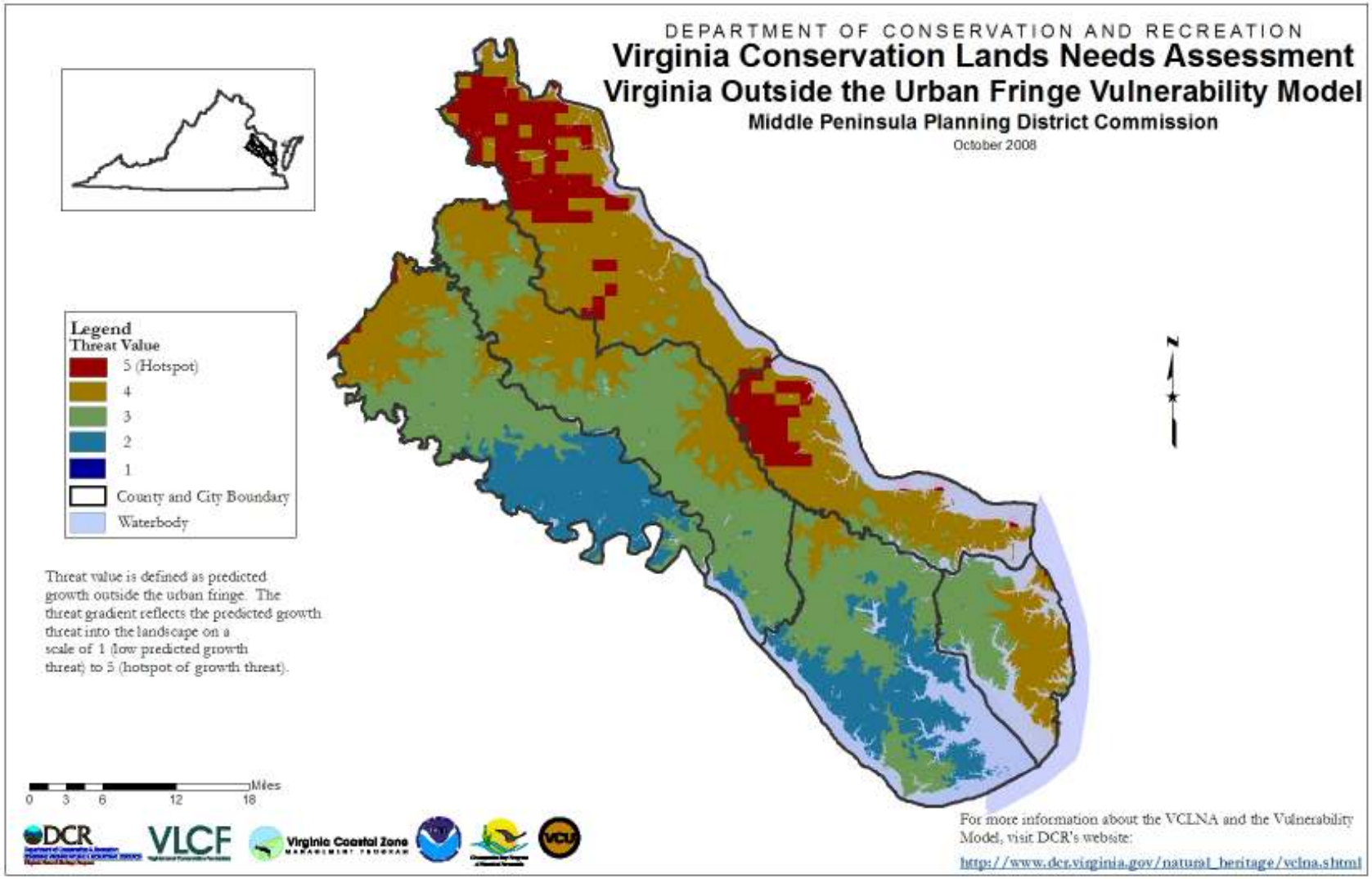

Figure 73. PDC 19 Crater Vulnerability Model.

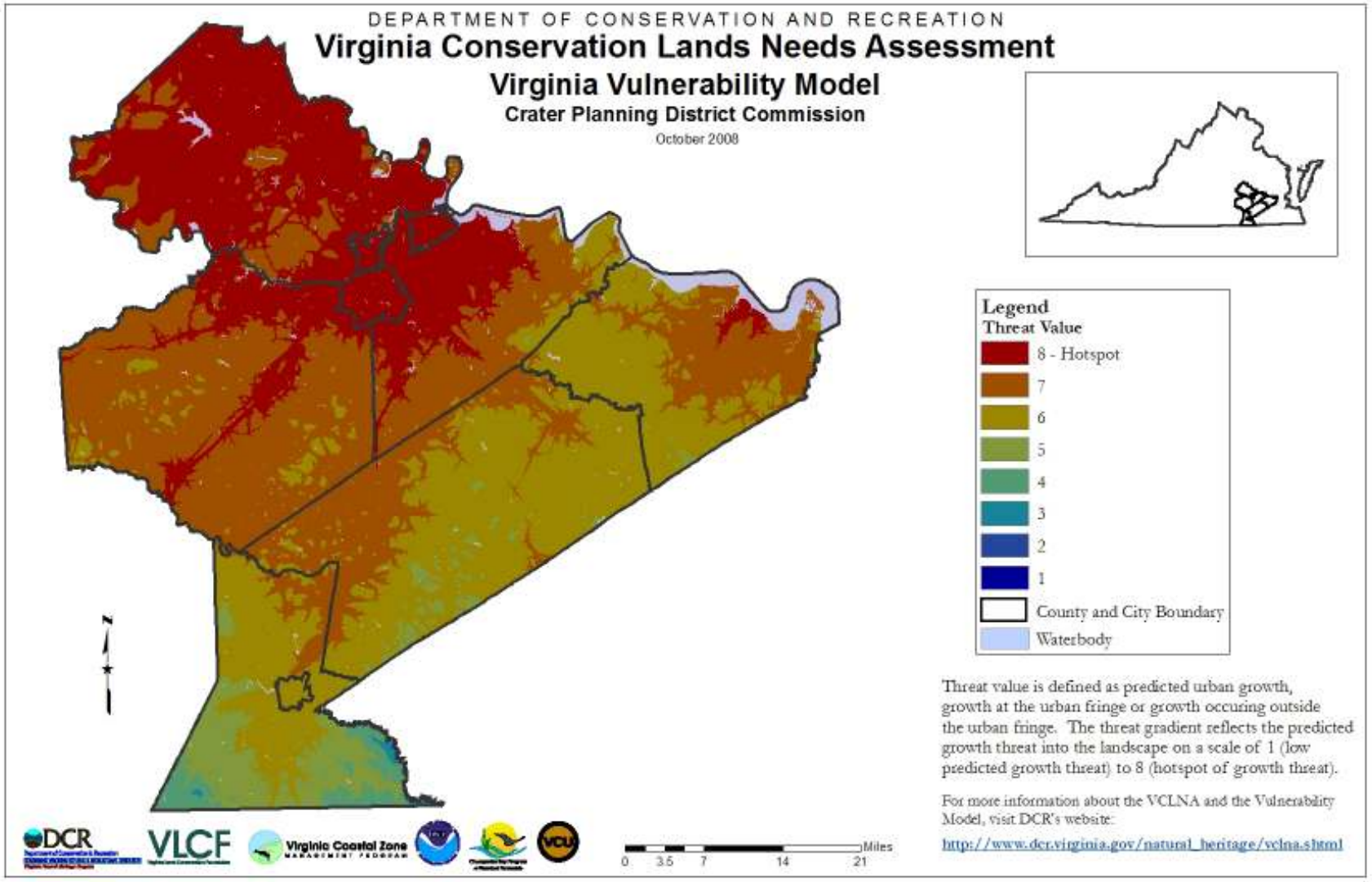

Figure 74. PDC 19 Crater Urban Vulnerability Model.

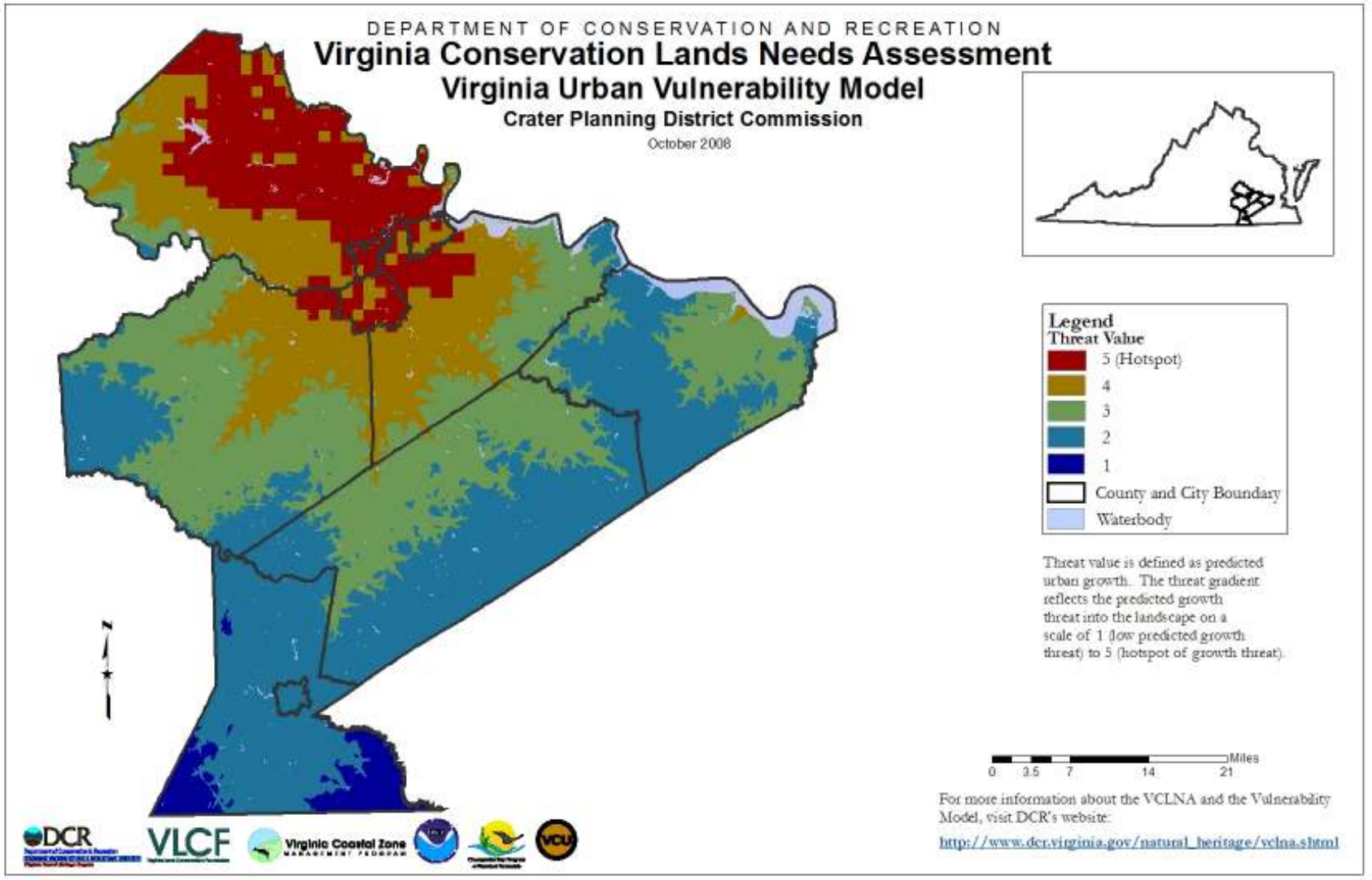

Figure 75. PDC 19 Crater Urban Fringe Vulnerability Model.

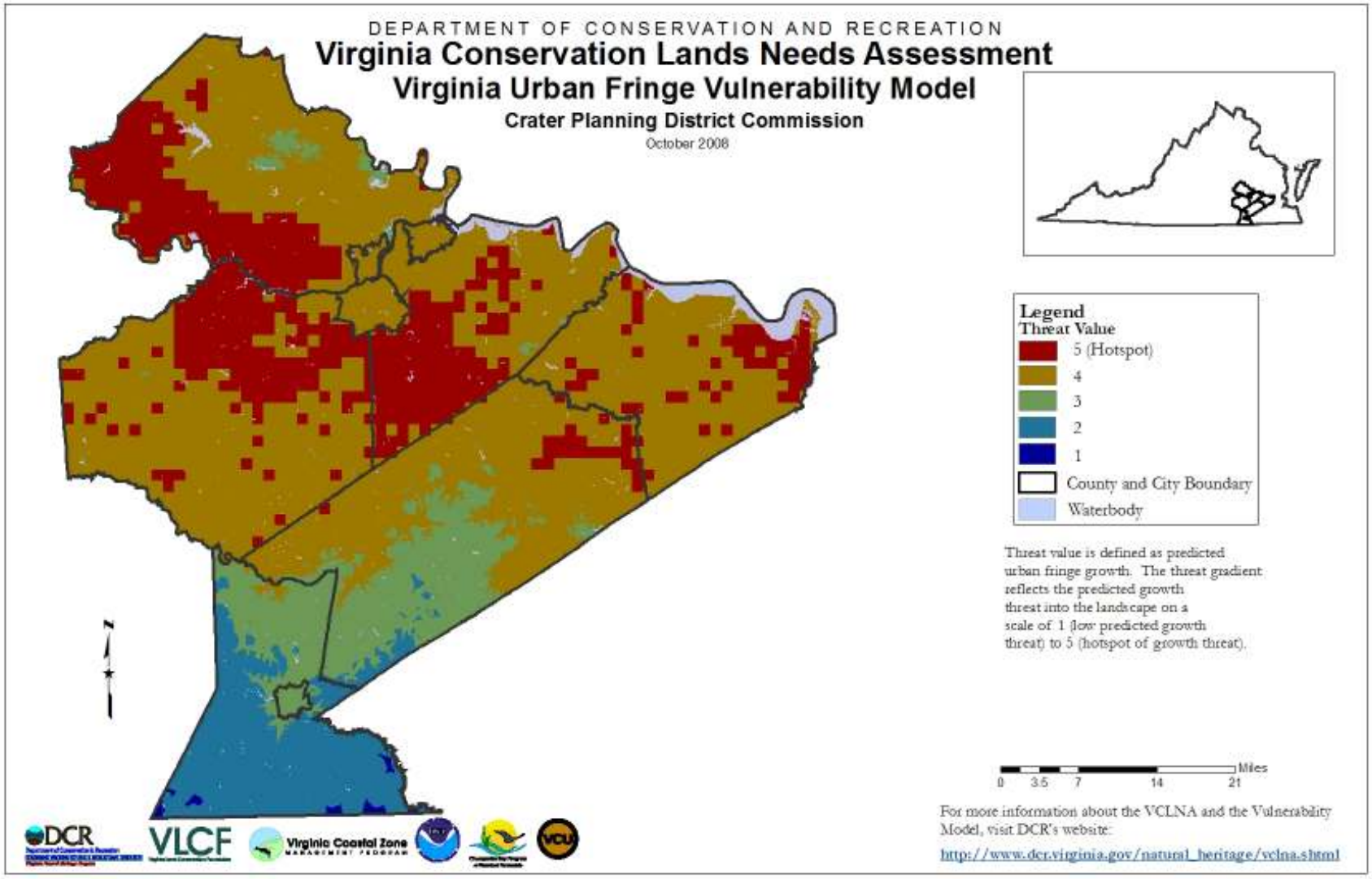

Figure 76. PDC 19 Crater Outside the Urban Fringe Vulnerability Model.

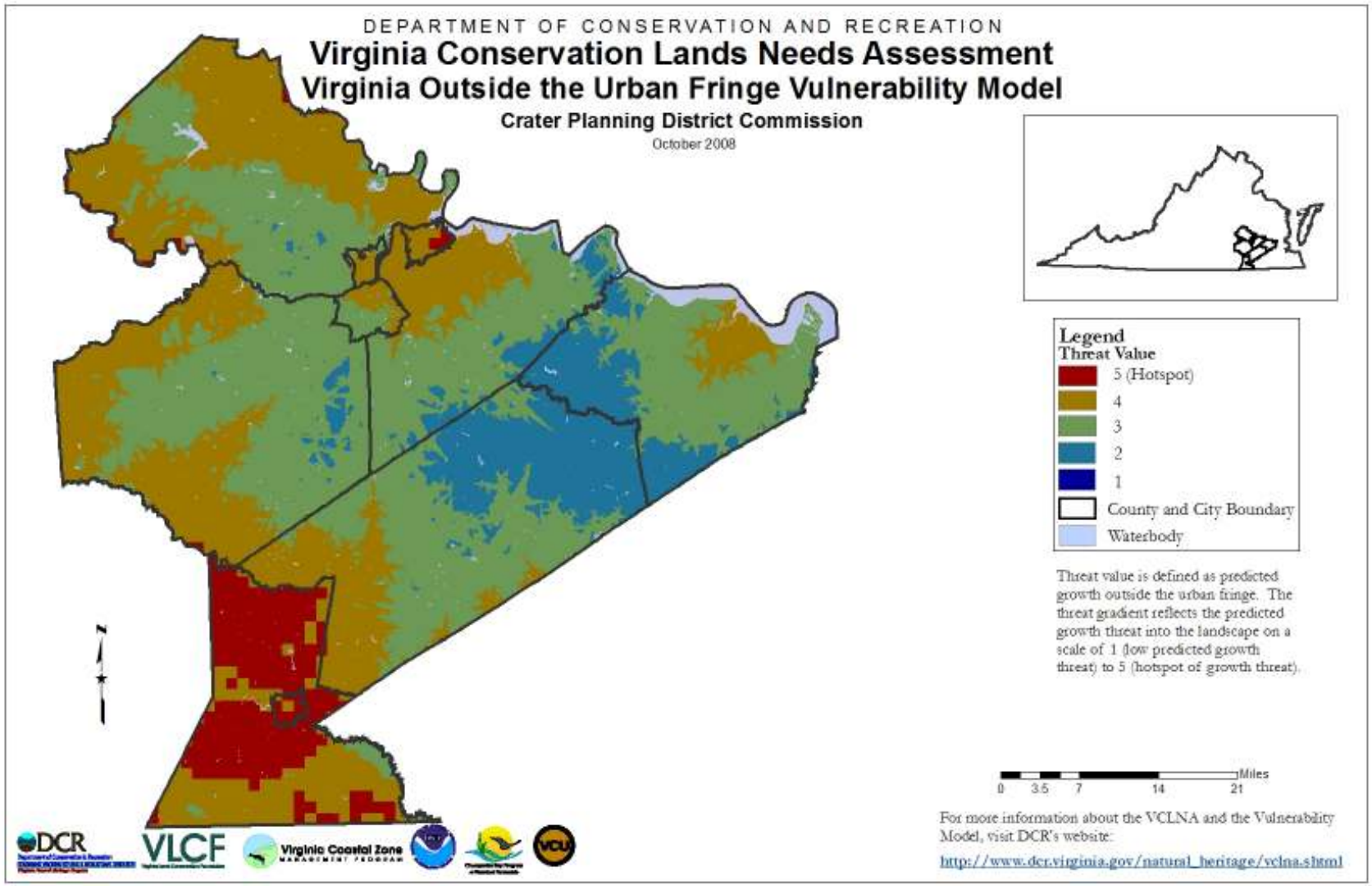

Figure 77. PDC 22 Accomack-Northampton Planning District Commission Vulnerability Model.

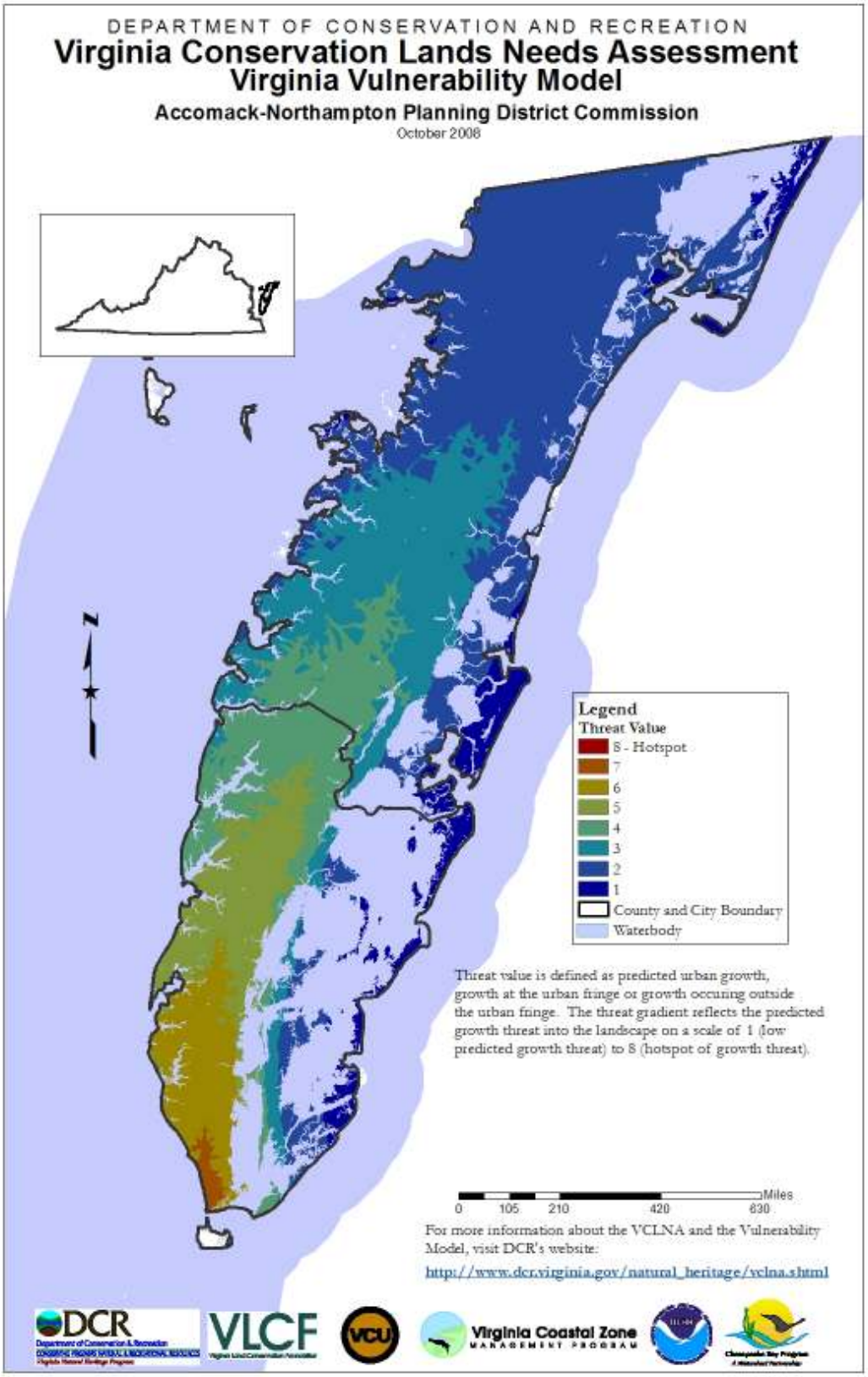

Figure 78. PDC 22 Accomack-Northampton Planning District Commission Urban Vulnerability Model.

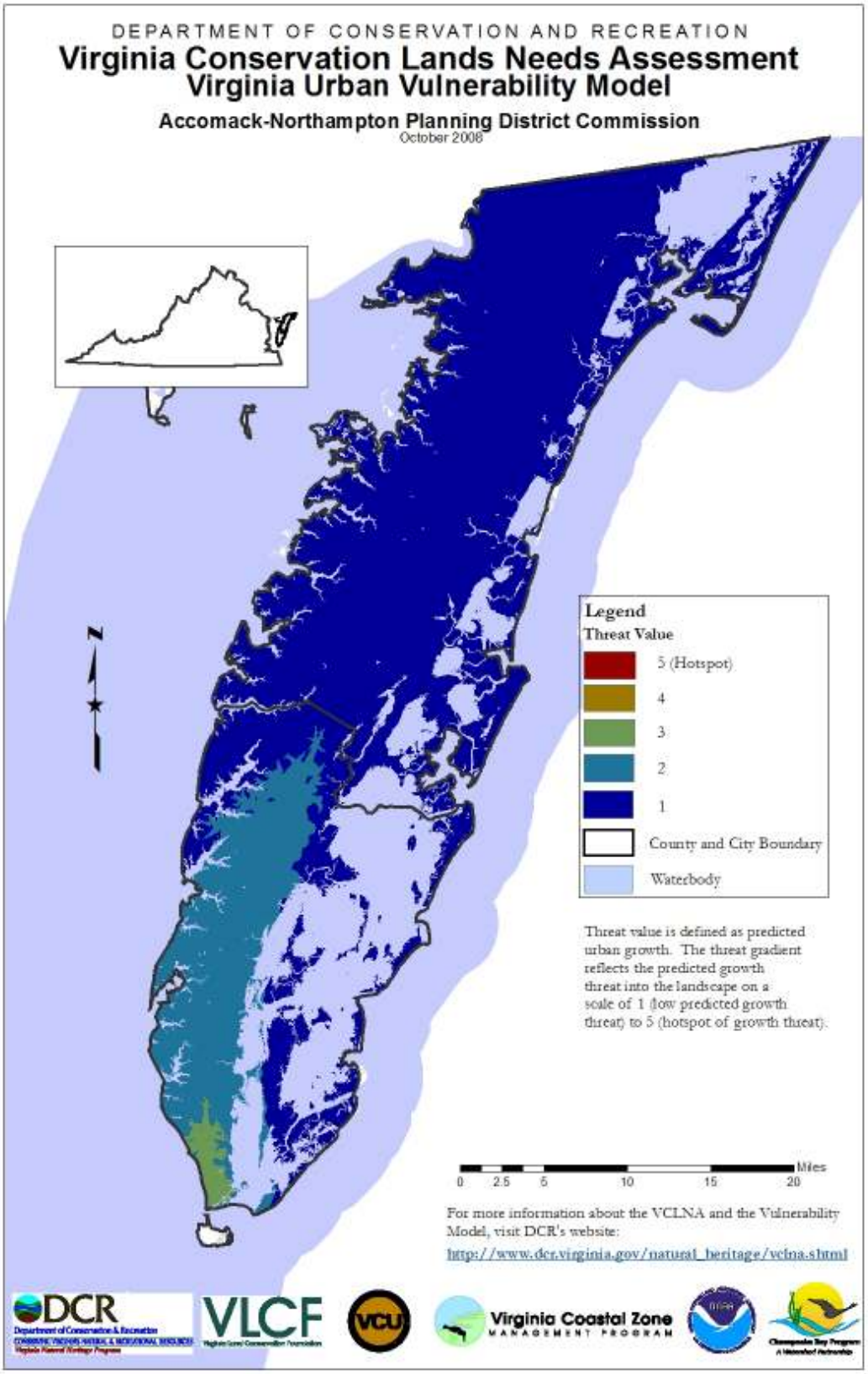

Figure 79. PDC 22 Accomack-Northampton Planning District Commission Urban Fringe Vulnerability Model.

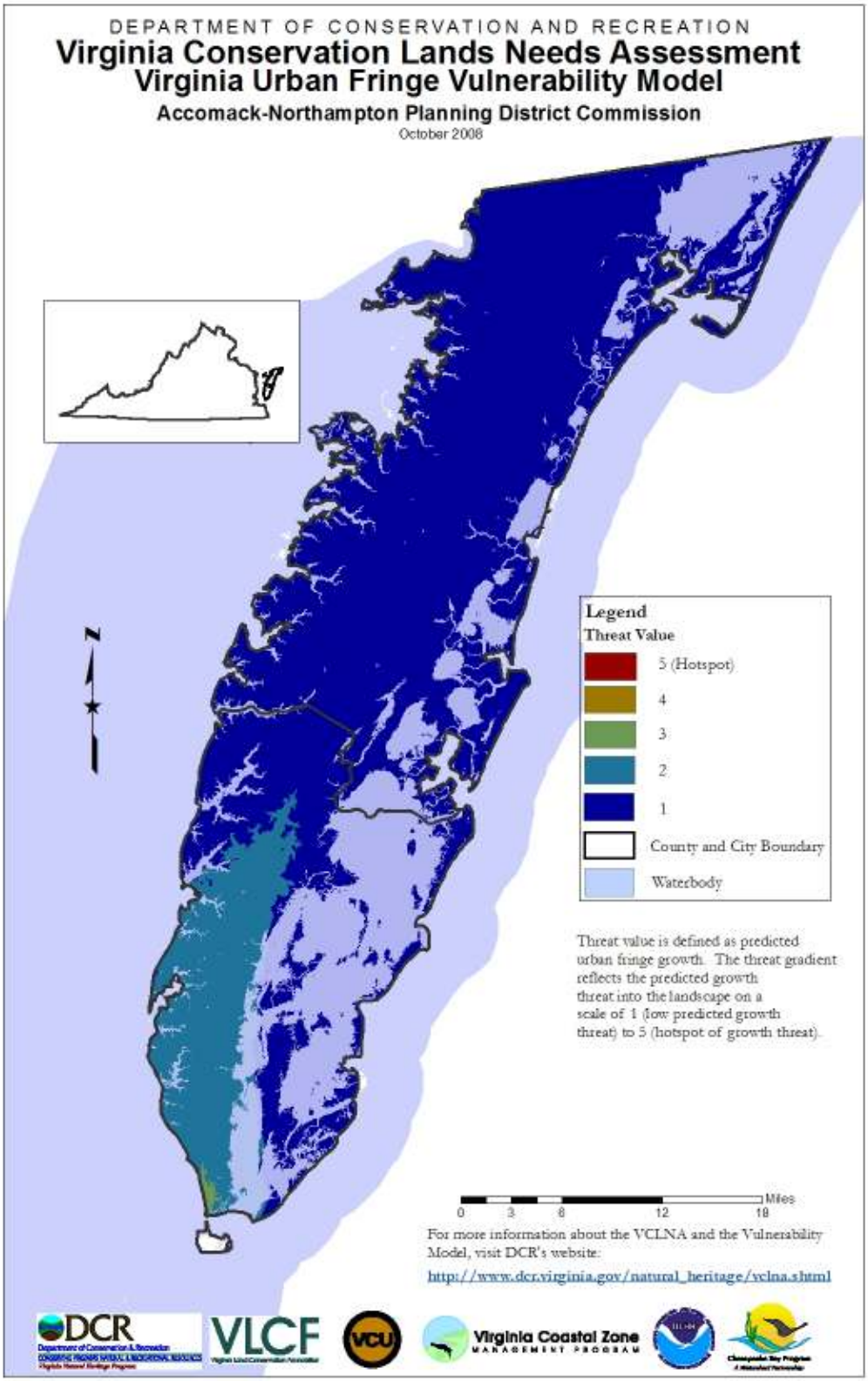

Figure 80. PDC 22 Accomack-Northampton Planning District Commission Outside the Urban Fringe Vulnerability Model

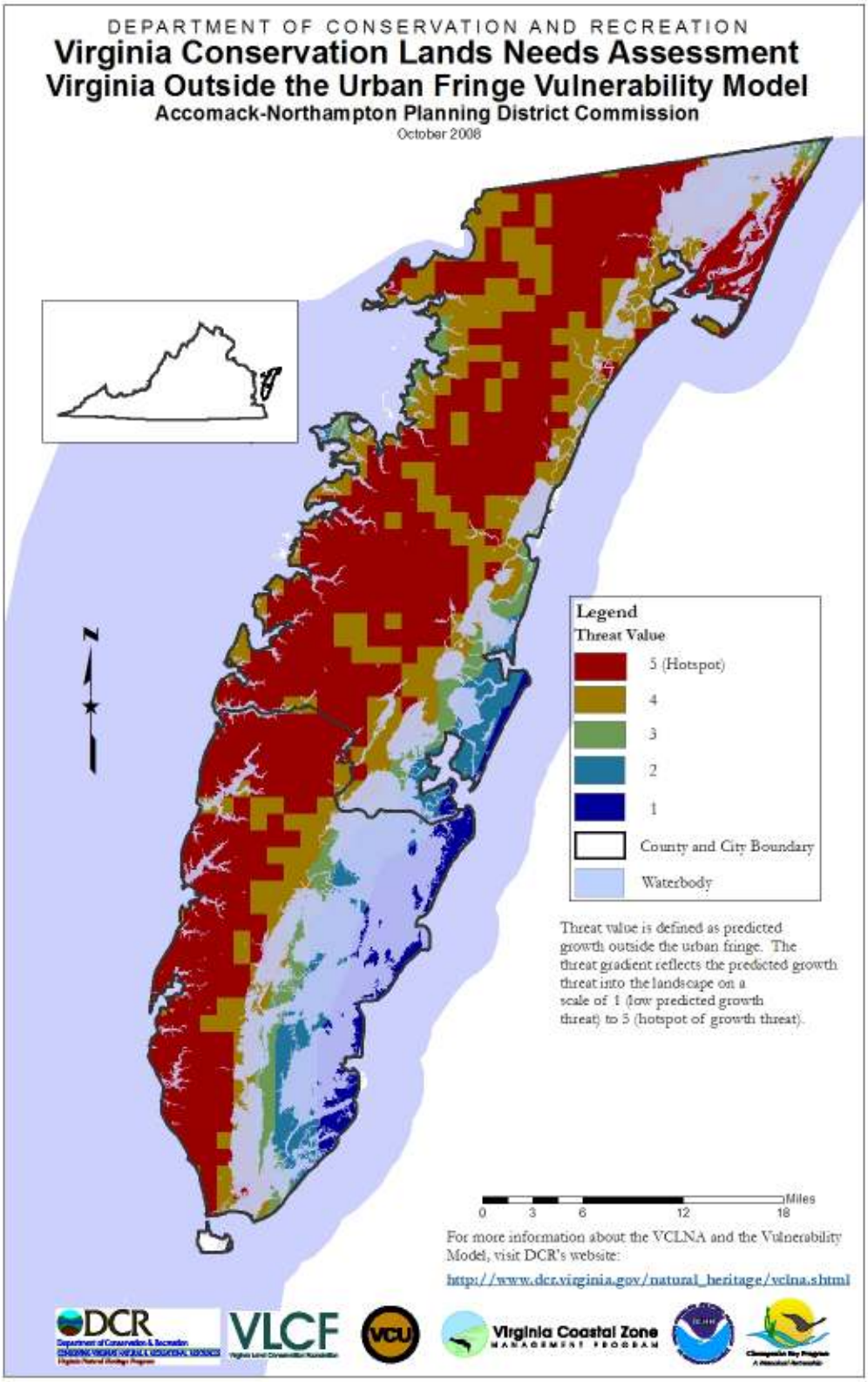

Figure 81. PDC 23 Hampton Roads Planning District Commission Vulnerability Model

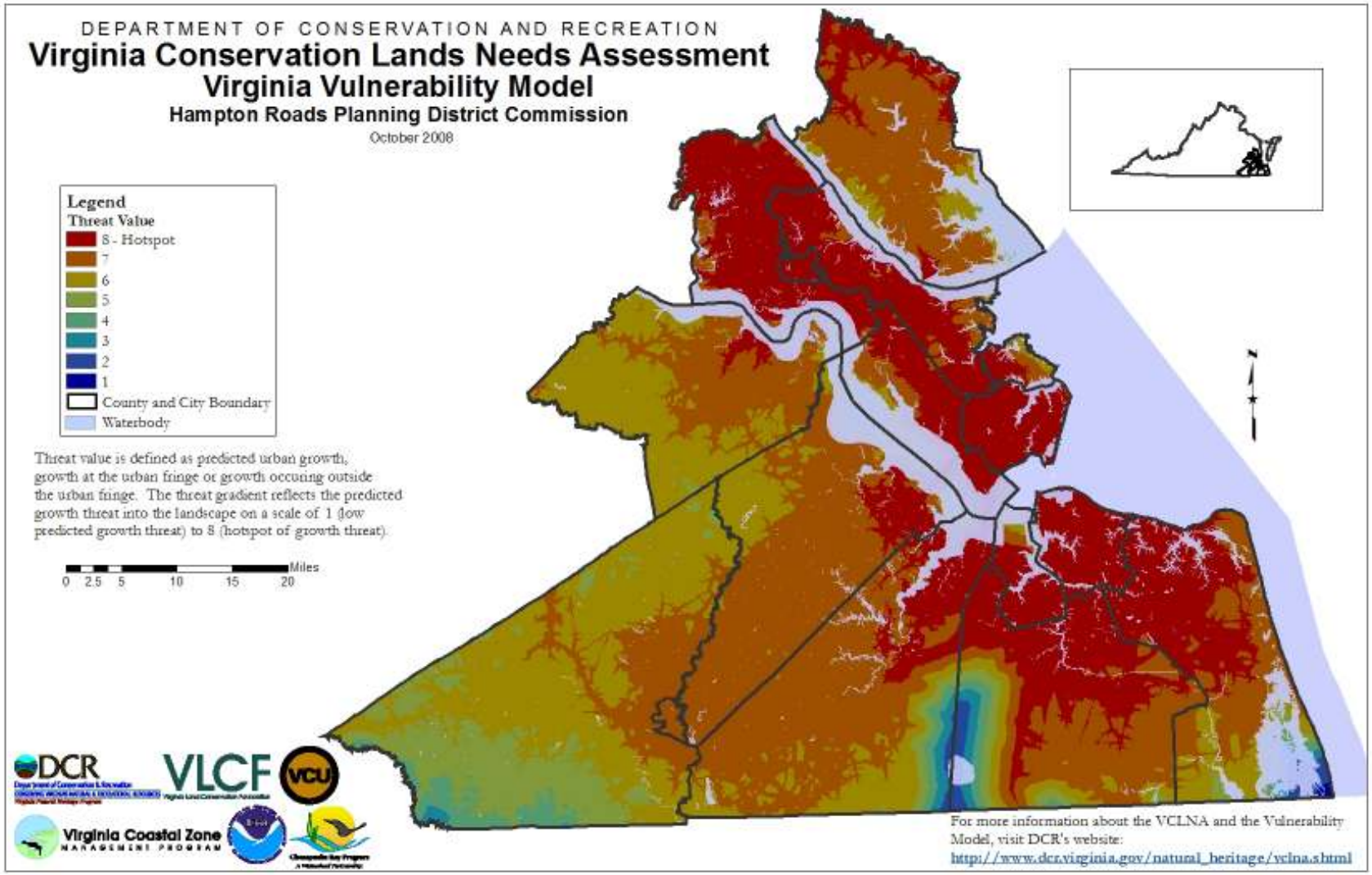

Figure 82. PDC 23 Hampton Roads Planning District Commission Urban Vulnerability Model

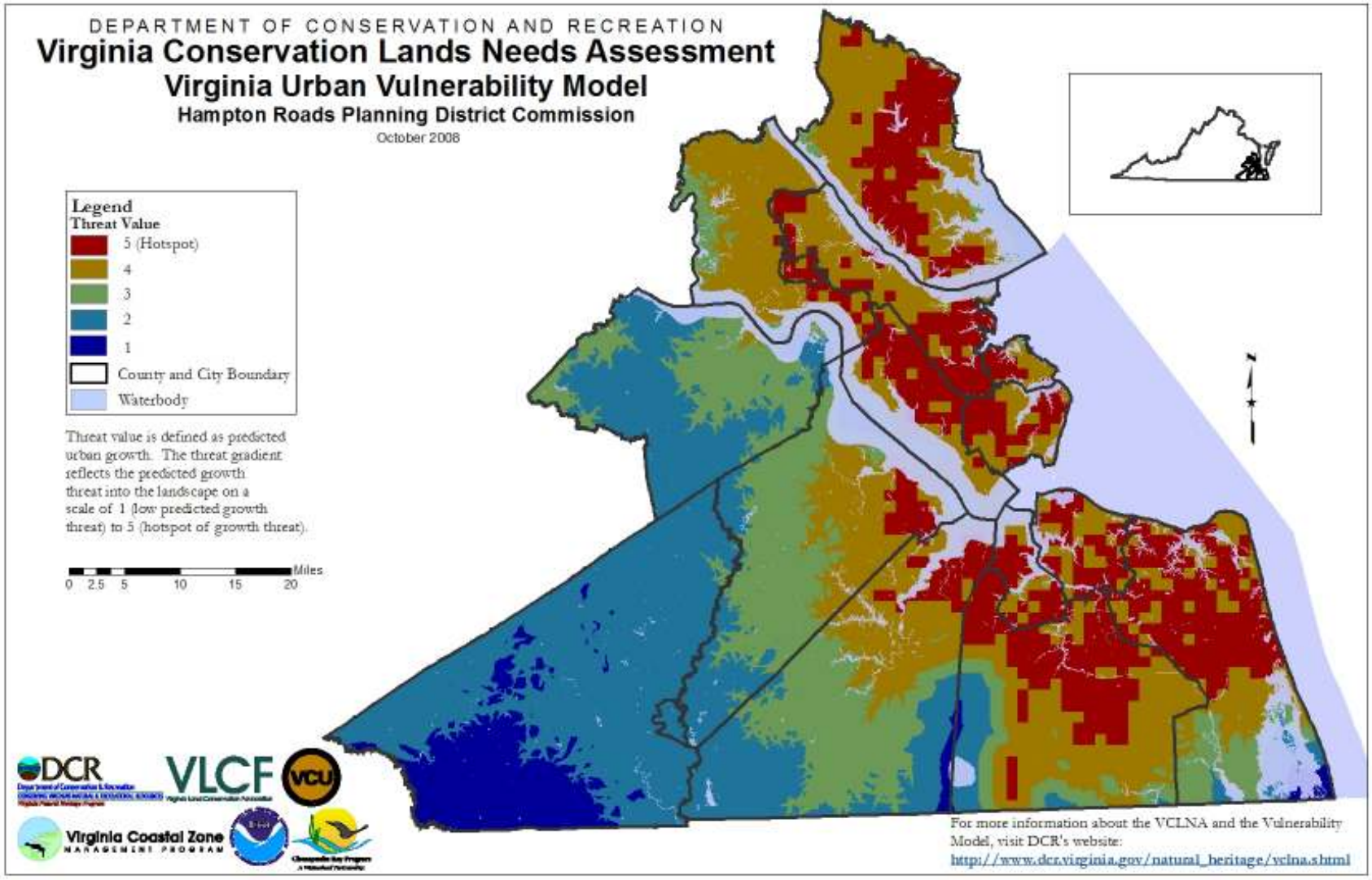

Figure 83. PDC 23 Hampton Roads Planning District Commission Urban Fringe Vulnerability Model

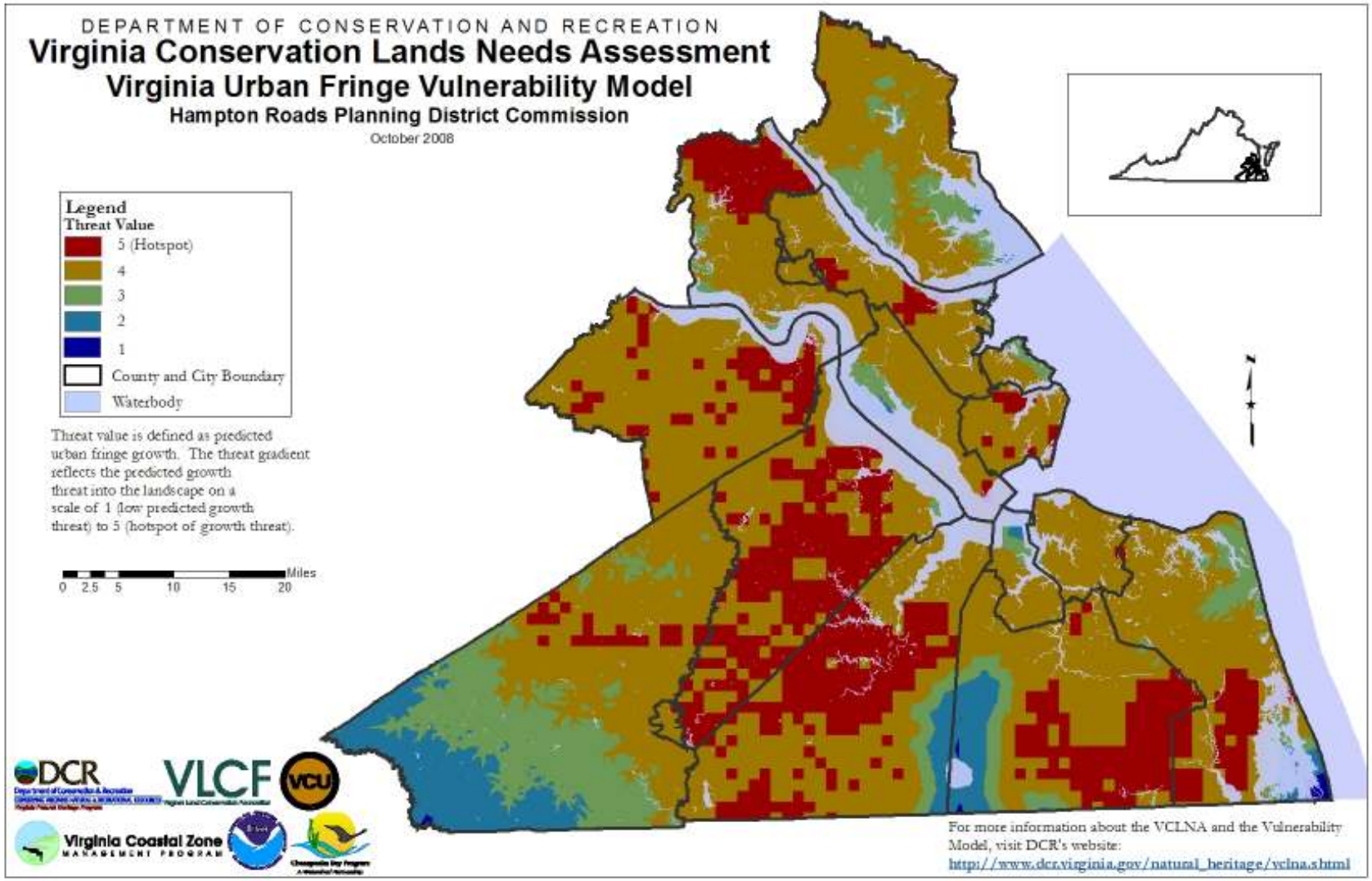

Figure 84. PDC 23 Hampton Roads Planning District Commission Outside the Urban Fringe Vulnerability Model

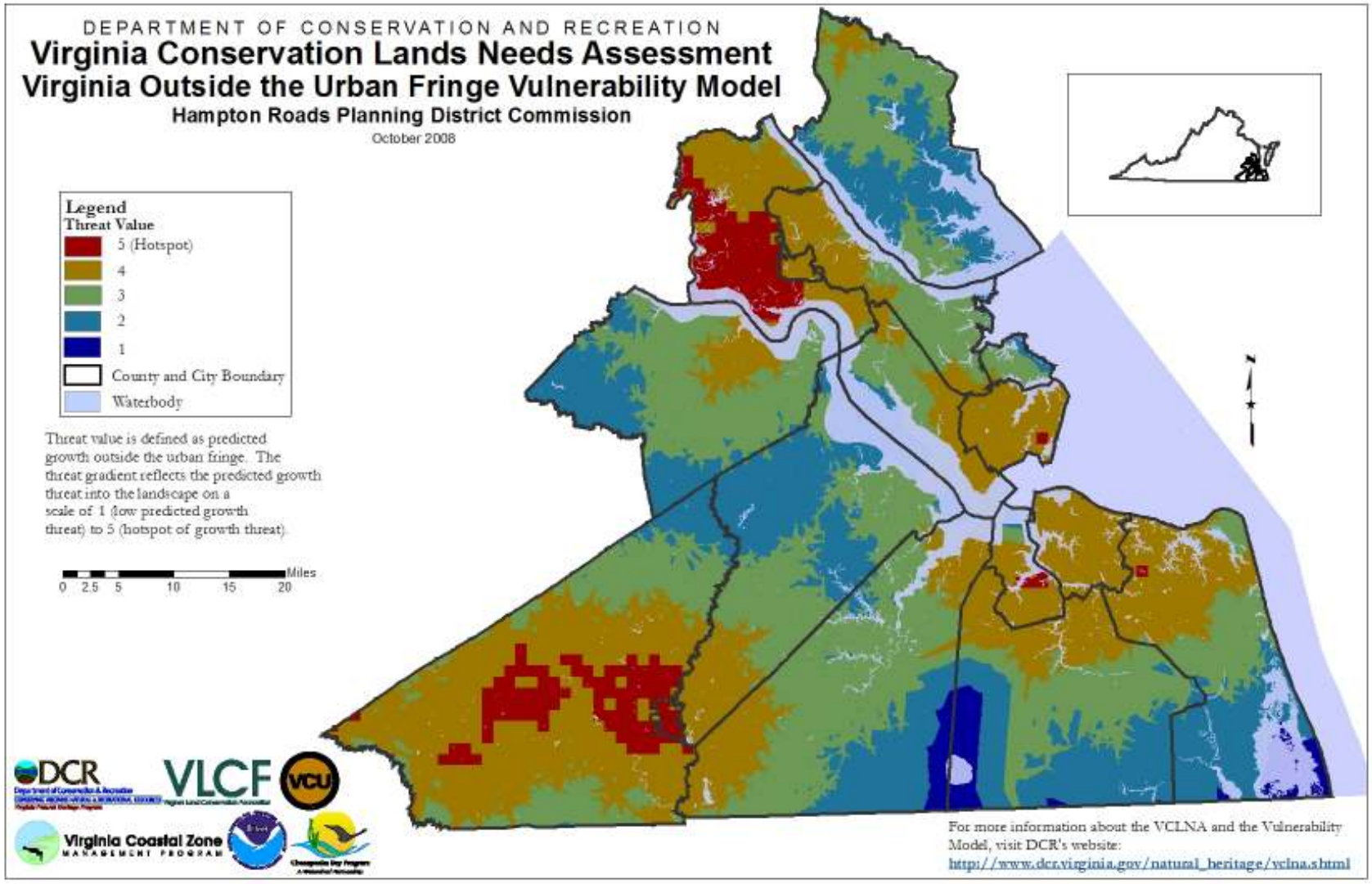

Figure 85. Coastal Zone Vulnerability Model.

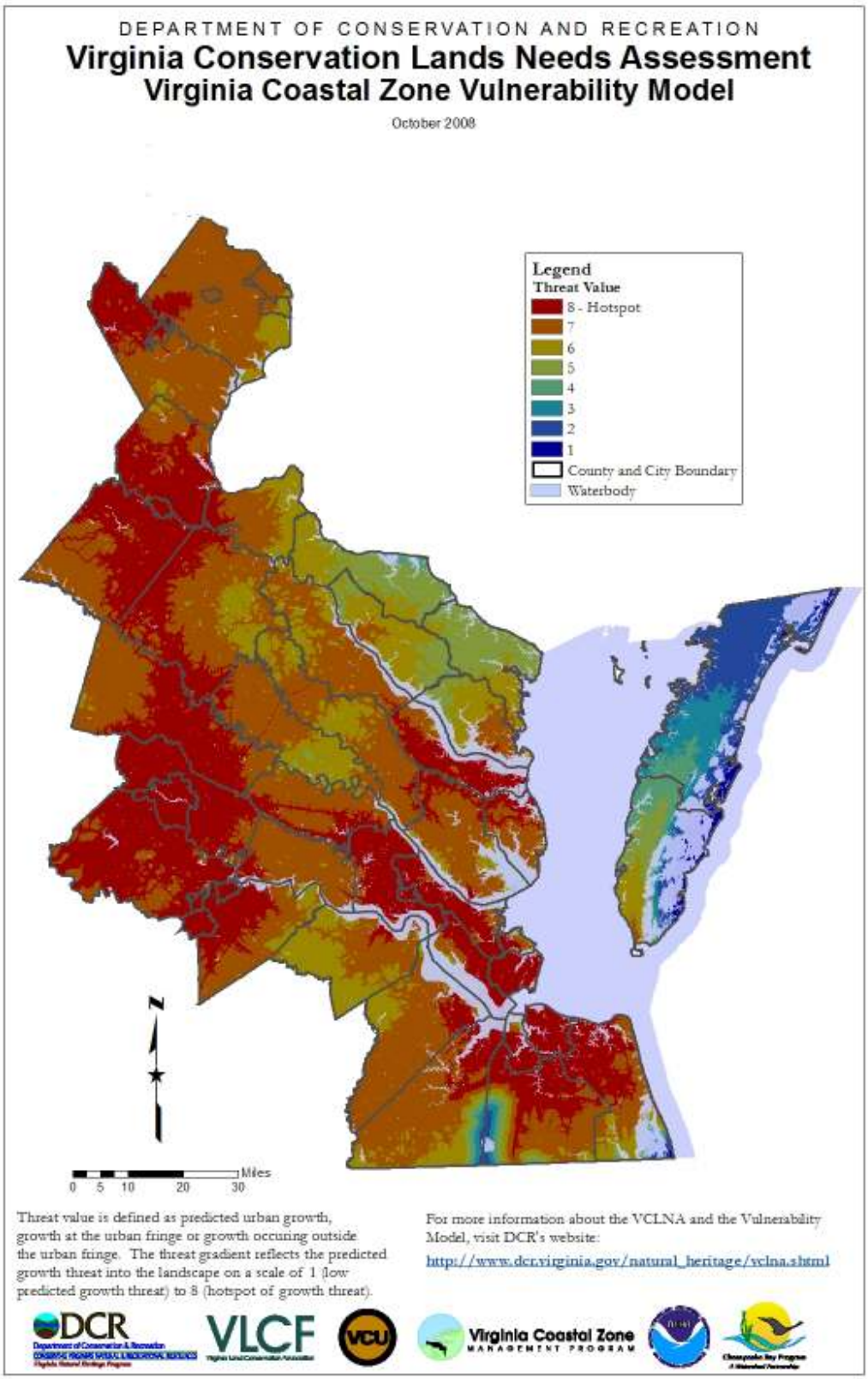

Figure 86. Coastal Zone Urban Vulnerability Model.

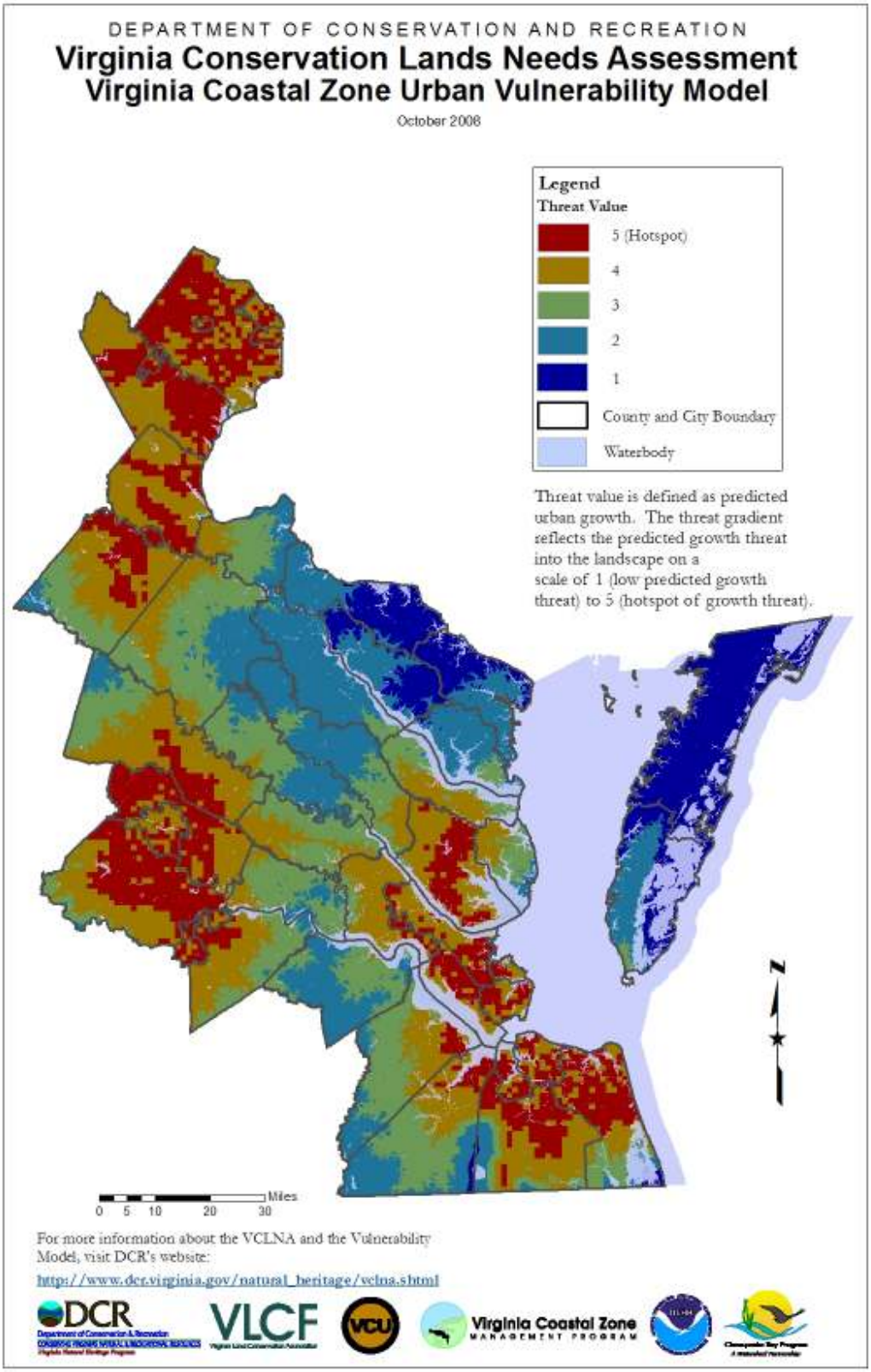

Figure 87. Coastal Zone Urban Fringe Vulnerability Model.

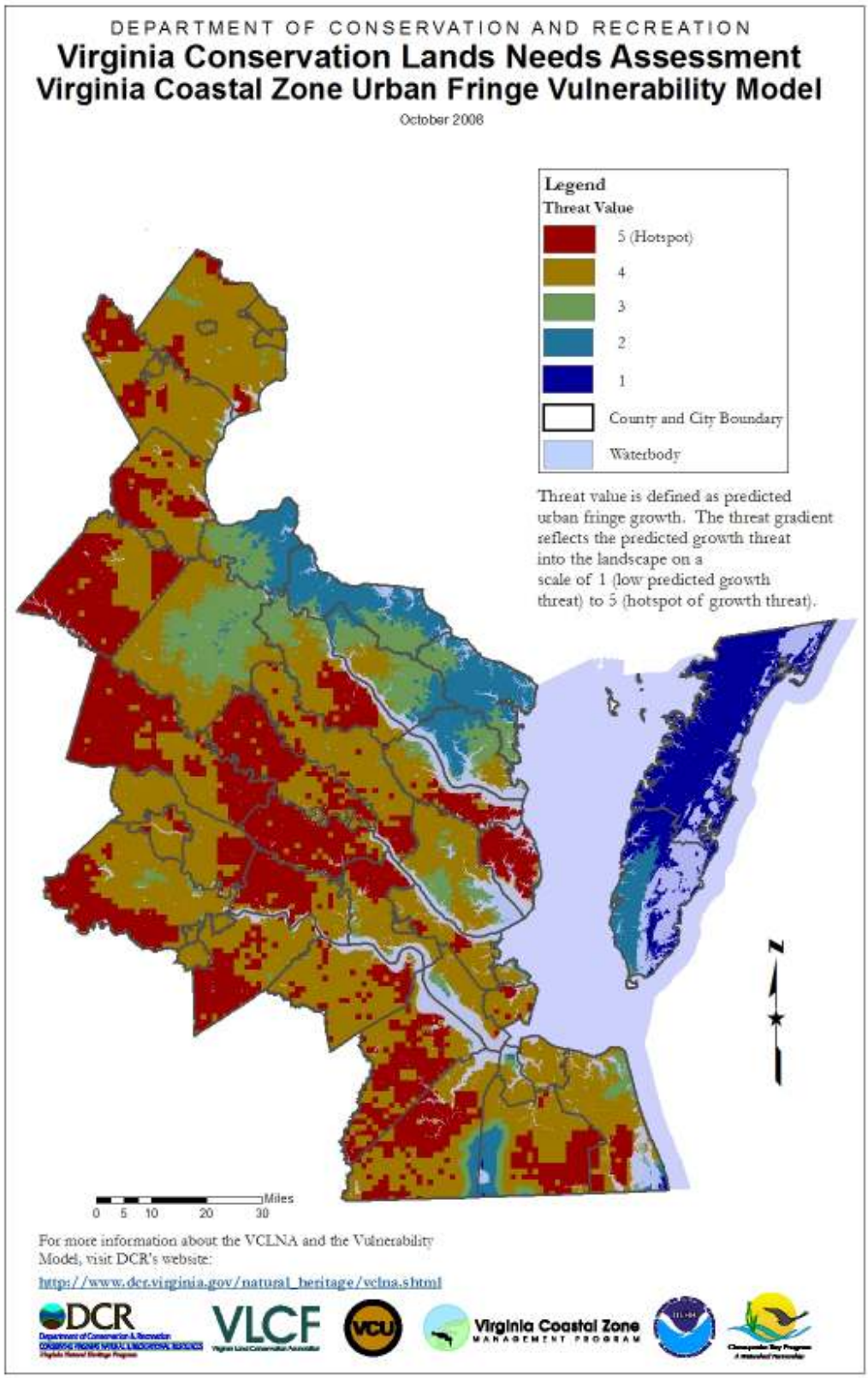

Figure 88. Coastal Zone Outside the Urban Fringe Vulnerability Model.

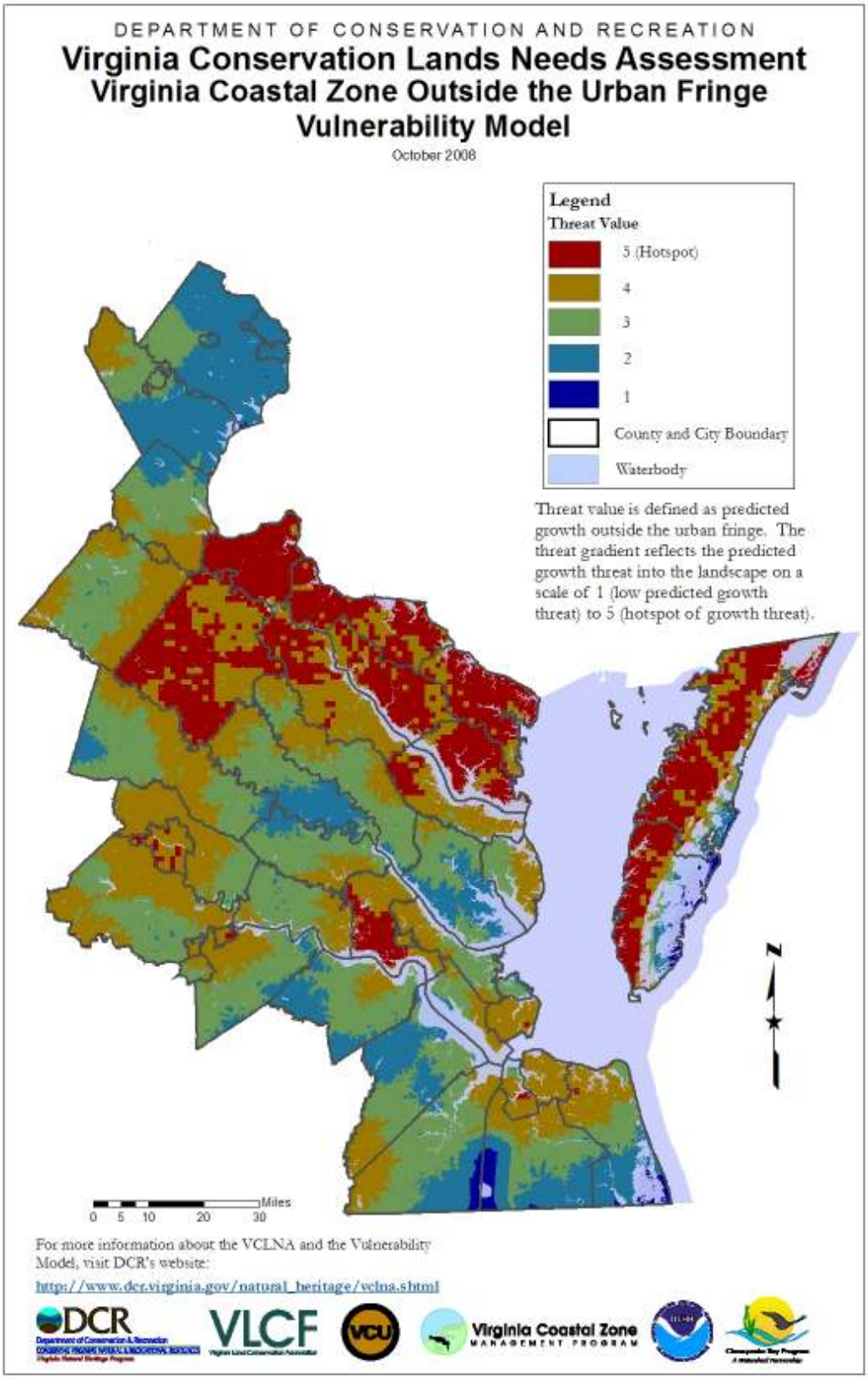

Figure 89. Virginia Vulnerability Model.

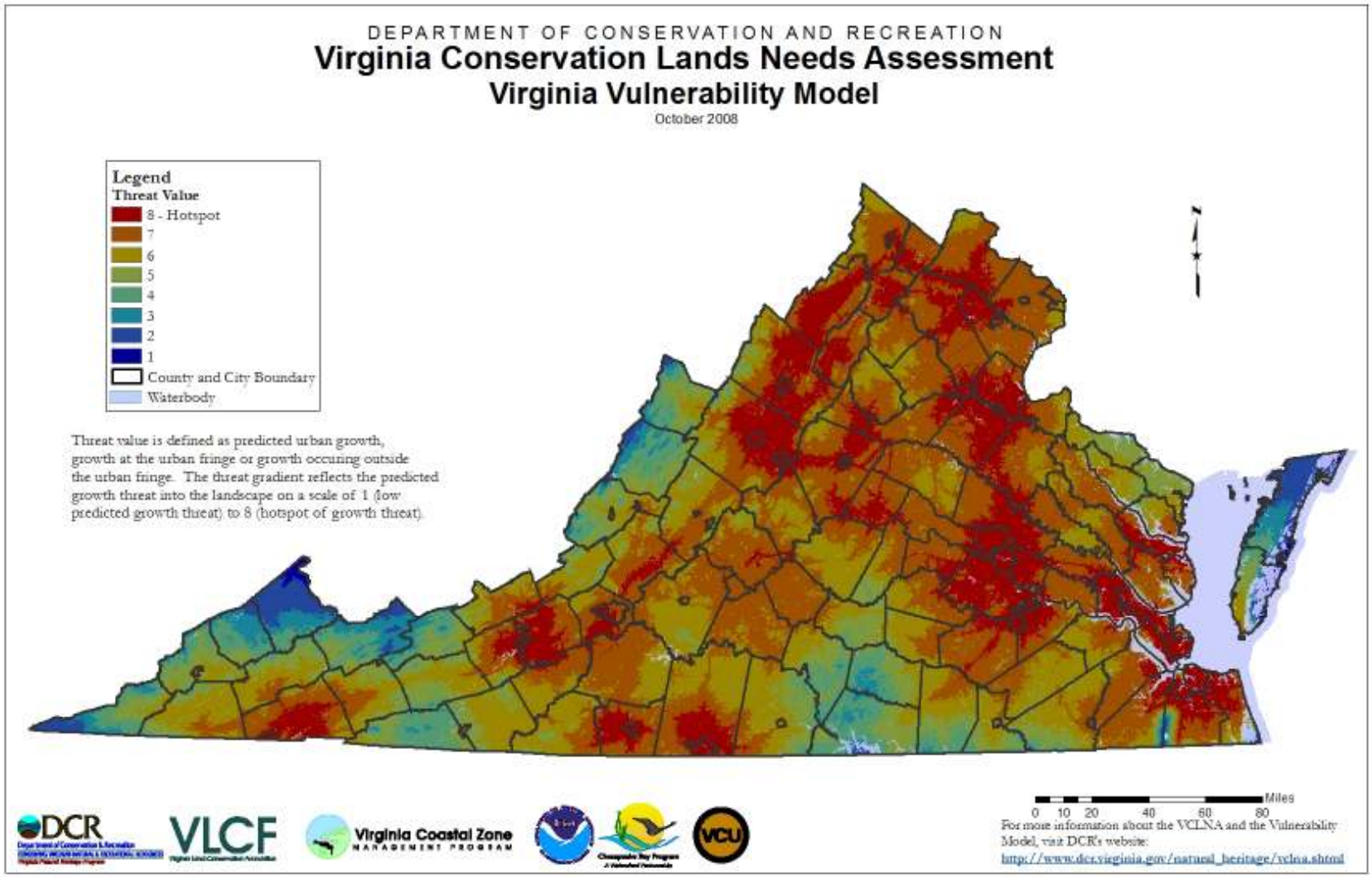

Figure 90. Virginia Urban Vulnerability Model.

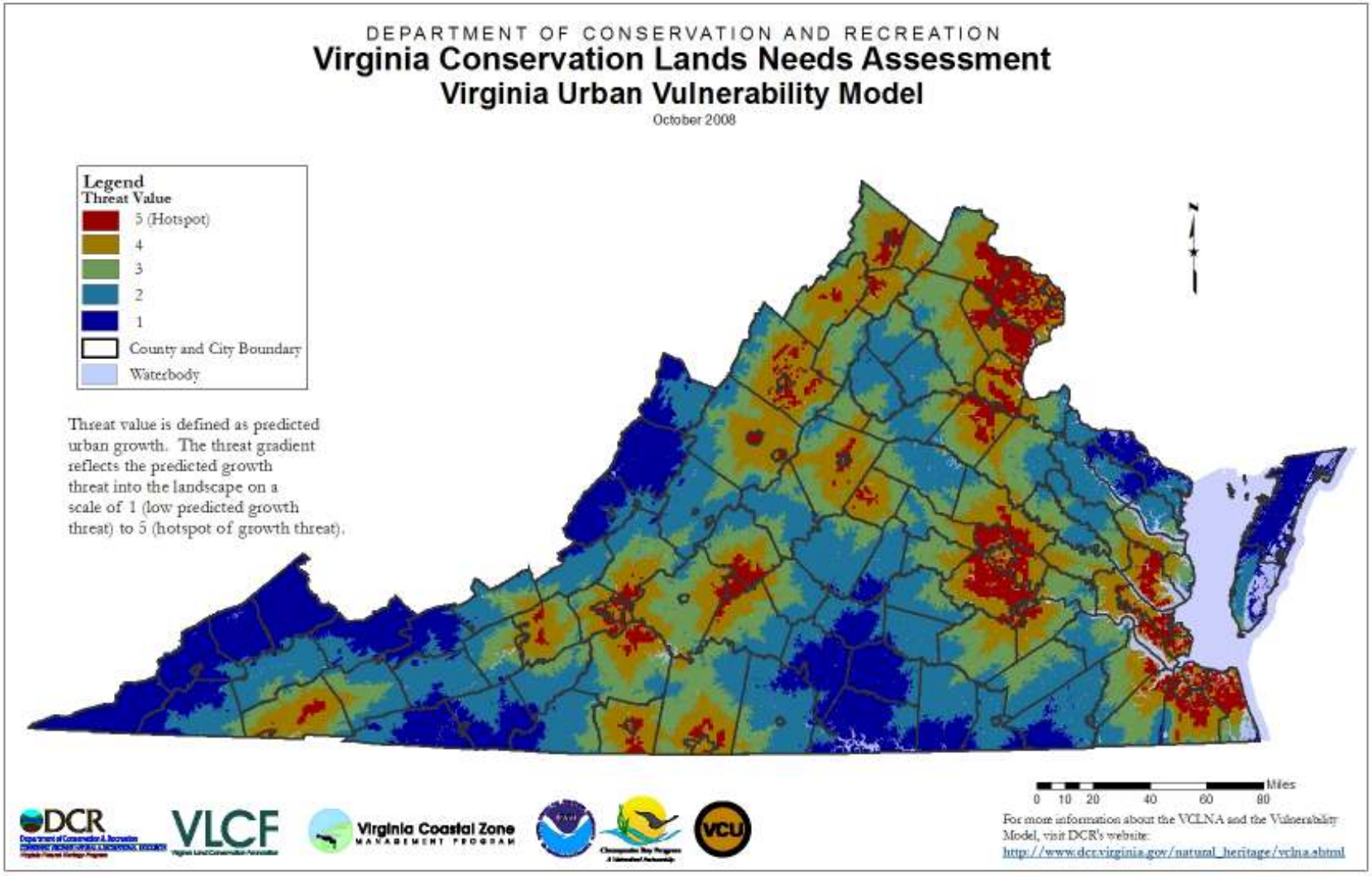

Figure 91. Virginia Urban Fringe Vulnerability Model.

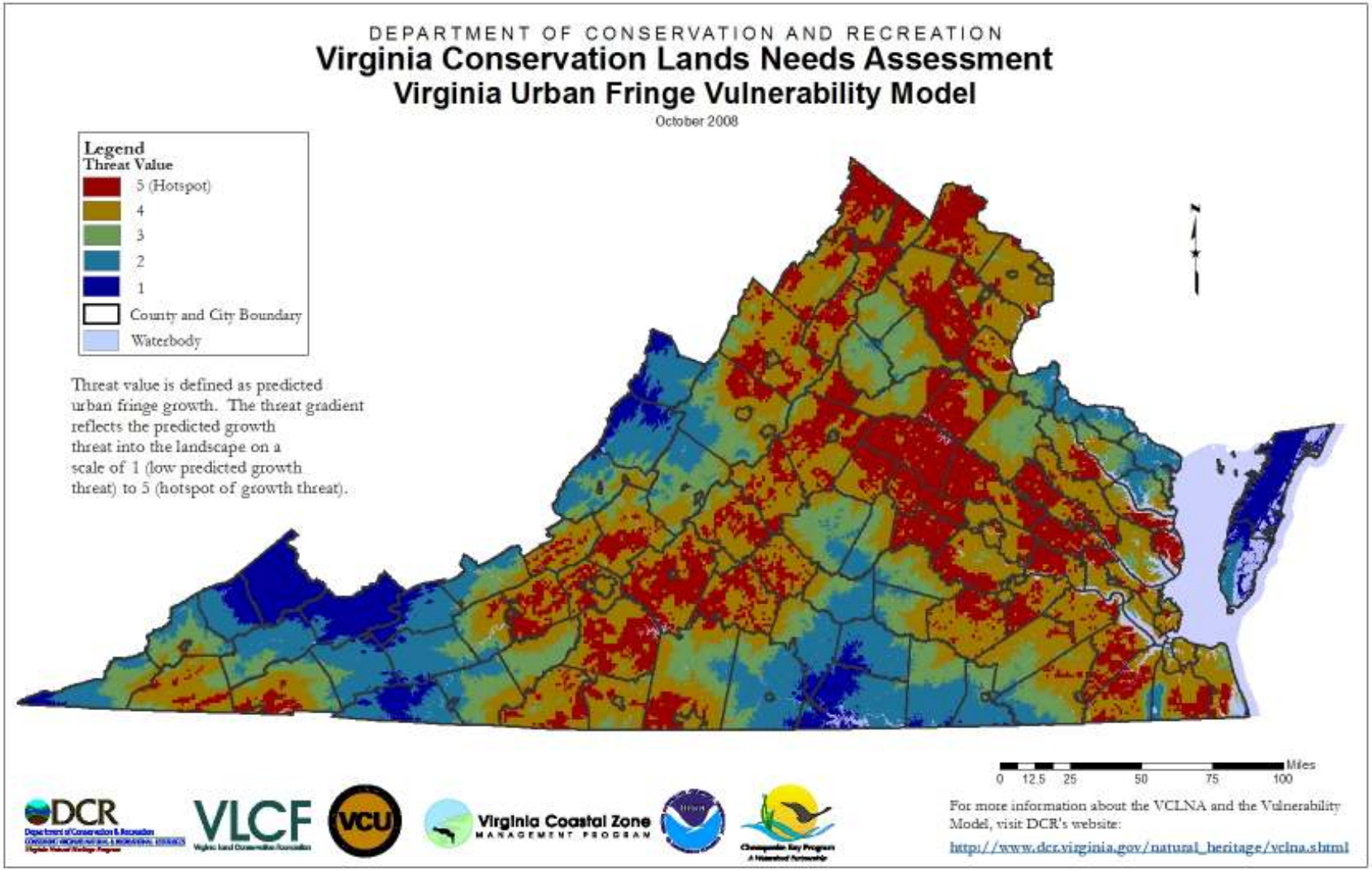
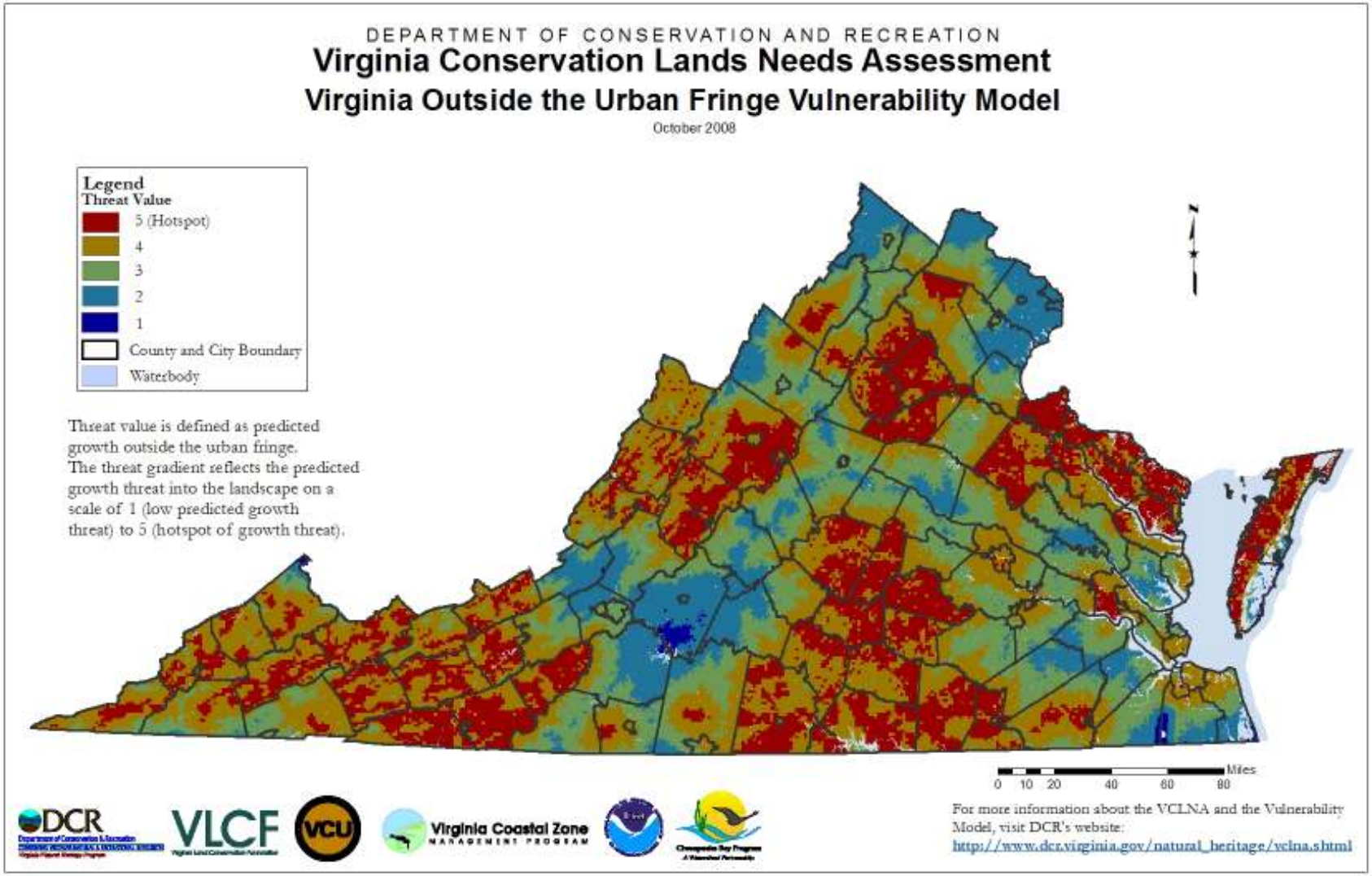
Figure 92. Virginia Outside the Urban Fringe Vulnerability Model.